# DESIGNING A NOVEL CLINICAL PRACTICE PRODUCT: MANUAL CHEST PHYSIOTHERAPY TRAINING SYSTEM FOR PHYSIOTHERAPY STUDENTS

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SELAMİ ERDOĞAN

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**DESIGNING A NOVEL CLINICAL PRACTICE PRODUCT: MANUAL CHEST PHYSIOTHERAPY TRAINING SYSTEM FOR PHYSIOTHERAPY STUDENTS**

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## ABSTRACT

### DESIGNING A NOVEL CLINICAL PRACTICE PRODUCT: MANUAL CHEST PHYSIOTHERAPY TRAINING SYSTEM FOR PHYSIOTHERAPY STUDENTS



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This thesis study aims to research the clinical practice product design stages in respiratory physiotherapy education and to transfer the knowledge and experience gained throughout the process to the designers. The research through design (RtD) approach was accepted as the focus of the study. The study includes a comprehensive literature review with preliminary research to explore respiratory physiotherapy and manual chest physiotherapy education. An expert interview was held to investigate the current situation in physiotherapy education and the instructor-student relationship. In addition, the versions of the education system design (Physiocircle V1-V2) that emerged in the process were used in the focus group studies. Information was obtained from the participants under various concepts such as feedback and comments, motivation, and obstacles. As a result, suggestions are presented for designers who want to develop a clinical practice product.



Keywords: Mannequin Simulators, Respiratory Physiotherapy, Manual Chest Physiotherapy, Research Through Design

# ÖZ

## YENİ BİR KLİNİK UYGULAMA ÜRÜNÜ TASARLAMAK: FİZYOTERAPİ ÖĞRENCİLERİ İÇİN MANUEL GÖĞÜS FİZYOTERAPİ EĞİTİM SİSTEMİ

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Bu tez çalışması, solunum fizyoterapisi eğitimindeki klinik uygulama ürün tasarım aşamalarını araştırmayı ve süreç boyunca edinilen bilgi ve deneyimleri tasarımcılara aktarmayı amaçlamaktadır. Tasarım Yoluyla Araştırma (RtD) yaklaşımı, çalışmanın odak noktası olarak kabul edilmiştir. Çalışma, solunum fizyoterapisini ve manuel göğüs fizyoterapisi eğitimini keşfetmeye yönelik ön araştırmalarla birlikte kapsamlı bir literatür taraması içermektedir. Fizyoterapi eğitimindeki mevcut durumu ve eğitmen-öğrenci ilişkisini araştırmak amacıyla uzman görüşmesi yapılmıştır. Ayrıca odak grup çalışmalarında eğitim sistemi tasarımının (Physiocircle V1-V2) süreç içerisinde ortaya çıkan versiyonları kullanılmıştır. Geribildirim ve yorumlar, motivasyon, engeller gibi çeşitli kavramlar altında katılımcılardan bilgi alınmıştır. Sonuç olarak, bu çalışma kapsamında klinik eğitim ürünü geliştirmek isteyen tasarımcılar için bir dizi öneriler sunulmuştur.

Anahtar Kelimeler: Simülasyon Mankenleri, Solunum Fizyoterapisi, Manuel Göğüs Fizyoterapisi, Tasarım Yoluyla Araştırma

To Mom, Dad, Pelin & Breathall

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You are all deeply loved.

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# CHAPTER 1

# INTRODUCTION

Today, due to the COVID-19 pandemic being effective worldwide, there has been a significant increase in people with breathing difficulties. According to the report released by the World Health Organization in May 2022, more than 522 million confirmed cases and more than six million deaths had been reported globally (World Health Organization, 2022). In addition, respiratory disorders caused by air pollution, tobacco products, and chronic respiratory diseases caused by genetic mutations also affect more than 500 million people worldwide (World Health Organization, 2008).

The increasing number of patients created a need for qualified healthcare professionals to participate in the treatment processes of patients with respiratory conditions. At this point, physiotherapists who are competent in respiratory physiotherapy have an essential role in the treatment processes of these patients (Clini & Ambrosino, 2005). Eurostat's 2018 report stated that 563,000 physiotherapists were working in the EU-27, equivalent to an average of 126 physiotherapists per 100,000 inhabitants. According to the same report, 5306 physiotherapists were working in Turkey. It averages 6.5 physiotherapists per 100,000 people (EUROSTAT, 2018). This rate, less than 1 in 20 of the European average, shows that the number of student physiotherapists should be increased to meet the number of physiotherapists needed in our country.

From a broader perspective, the increasing number of students will increase the number of students per instructor, which may lead to a decrease in the quality of education. In addition, the growing number of students gradually limits the time and experience students can gain by doing hands-on practice with patients during their education. Therefore, new clinical teaching methods should be considered to prepare students for clinical practice (Mandrusiak et al., 2014).

Technological advances enable the development of innovative products in the medical education industry, and these products need collaboration between designers and healthcare providers. As Panescu (2009) stated, besides the necessity of a user-centered design process for a successful medical product, designers have critical roles in contributing to various fields (Panescu, 2009). They can work at essential points of the medical product development process, ensuring interaction with the end-user, determining user needs, product design, and monitoring user tests. In addition, they should be in close contact with end-users such as physiotherapy students and professionals (Nillson & Sheppard, 2018).

## 1.1 Problem Definition

The entry-level education of students in the health professions aims to equip them with the necessary knowledge, skills, and professional behaviors to work safely and competently in the clinical environment. The entry-level study programs include collaboration between universities and clinical facilities, enabling clinical visits to prepare students for professional life (Chipchase et al., 2012). However, clinical practice faces limitations due to the increasing number of students and insufficient clinical facilities and educators (Mandrusiak et al., 2014).

On the other hand, research has shown that senior students feel ‘‘useless, unable to contribute to patient care because they had insufficient knowledge or skills’’ during the transition to working life (Radcliffe & Lester, 2003, p.35). At that point, the clinical practice provides the chance to experience real-life cases as a student and prepares them psychologically for working life. Considering all these reasons in a broad perspective, the design processes and the studies to be carried out in clinical practice will contribute to the education process of health professions students and educators.

There are previous studies on the role of designers in the medical product development process. However, in clinical practice, there need to be more suggestions that explore this process with the research through design method. In projects involving different disciplines, it is difficult for researchers to create concepts that can be fully understood by stakeholders (Gaziulusoy & Boyle, 2013). The research through design approach ensures a common language with stakeholders. In this way, stakeholders are more involved in the process, and their efficiency in concept development increases. For these reasons, research through design will be the most helpful method for managing the thesis and explaining the design stages.

This study investigates the methods used in respiratory physiotherapy education and carry out a collaborative design process with physiotherapy students and teachers. Transferring the knowledge, experience, and difficulties gained during this process will benefit designers motivated to work in medical education. The researcher chose this field because he has been involved in projects on health solutions that improve the quality of life of respiratory patients for over 3 years. Collaborative studies were carried out with the research and development team of engineers on the Physiocircle product developed during this thesis process. While the engineers in the team took part in the software and hardware development process, the researcher provided the planning of the whole process, making the design decisions, conducting the field studies, and transferring the knowledge and experience gained during the thesis process. The Physiocircle product, which emerged as a result of the research and field studies carried out during the thesis process, is a product that works with all its functions and is suitable for use. The Physiocircle product was developed with engineers and made ready for use in future academic studies in this field.

## 1.2 Aim and Goal of the Study

The literature review and expert interview outcomes, which will be explained later, present the importance of clinical practice in medical education. By reviewing the preliminary research data and existing literature, the study is based on the idea that qualified and comprehensive training in the clinical environment increases the quality of the education they receive and ensures that they are psychologically ready for the cases they may have encountered in real life. Thus, this study provides suggestions for designers and design students who want to develop a clinical practice product to improve their perspectives during the idea and concept generation stages.

The research objective is:

- Carrying out the design process with physiotherapy instructors and students within the scope of research through design,

The goals of the research are:

- Understanding of the best practice for designers in extracting knowledge from medical instructors and students,
- Conceptualizing the findings and experiences into a design suggestion for designers who motivated to work on clinical practice

## 1.3 Research Questions

The research questions of this thesis study are:

- What are the experiences of designers in the educational product and system development processes carried out with physiotherapy students and teachers?
- What are the challenges that industrial designers may encounter during the incorporation of medical education into industrial design processes?
- What should be considered when designing medical education products?

## 1.4 Structure of the Thesis

This thesis consists of six chapters. The first chapter is the introductory chapter which starts with the significance of clinical practice in physiotherapy education. In addition, the roles of designers in the medical product development process are mentioned. Later, the problem definition, aim, goal, and research questions are explained. Figure 1.1 presents the structure of the thesis.

**Chapter 1:** Introduction

- *Problem Definition*
- *Aim and Goal of the Study*
- *Research Questions*
- *Structure of the Thesis*

**Chapter 2:** Literature Review

- *Understanding of Medical Education*
- *Simulation as an Educational Tool*
    - *Standardised Patients*
    - *The Mannequin Simulator*
    - *Designing a Simulation Activity*
- *Respiratory Physiotherapy*
    - *Manual Chest Physiotherapy*
- *Research through Design (RtD)*
- *Summary and Discussion*

**Chapter 3:** Methodology

- *Preliminary Research: Expert Interview*
- *Expert Interview*
- *Field Study*
    - *Design of the Educational Training System, Physiocircle (V1-V2)*
- *Data Collection Techniques*
    - *Focus Group Studies*
- *Sampling*
- *Data Analysis: Affinity Diagram*

**Chapter 4:** RtD - Part 1

- *Determination of Initial Design Proposal*
- *Design of the 'Physiocircle - V1'*
    - *Training Vest - V1*
    - *Mobile Application - V1*
    - *Desktop Application - V1*
- *Outcomes of the Field Study*
    - *Findings, Results and Suggestions*

**Chapter 5:** RtD - Part 2

- *Design of the 'Physiocircle - V2'*
    - *Training Vest - V2*
    - *Mobile Application - V2*
    - *Desktop Application - V2*
- *Outcomes of the Field Study*
    - *Findings, Results and Suggestions*
- *Further Suggestions for Later Versions*

**Chapter 6:** Conclusion

- Overview of the Study
- Research Questions Revisited
- Limitations of the Study
- Benefits of the Physiocircle
- Recommendations for Further Studies

Figure 1.1. Structure of the Thesis

In Chapter 2, the literature review about related subjects is presented. The literature review investigates the concepts of clinical practice, manual chest physiotherapy, and research through design.

Chapter 3 presents the methodology of the research. This chapter explains the process of determining the sources used in the literature research. Afterward, the expert opinion method explained, and information was given about the interview process with the expert. Explanations about the focus group study, another method used in the research, are also explained. Lastly, the process of analyzing the data obtained using the above-mentioned methods and the limitations of this process are explained.

Chapter 4 includes possible design suggestions that emerged from combining the findings obtained from the literature research and expert interview. After explaining the details of the design and development processes of the clinical practice (i.e., a physical product and mobile application), the findings and design suggestions that emerged as a result of the focus group studies with physiotherapy students and teachers are mentioned.

Chapter 5 elaborates on the proposed design revisions resulting from the focus group sessions completed with the first version. Second versions of the Physiocircle that includes training vest, mobile applications and desktop application are made, and second focus group study is held with physiotherapy teachers, students, and assistants. Suggested design revisions in future versions are indicated.

Finally, Chapter 6 starts with a brief overview of the study. Later, the research questions are revisited to make inferences from the findings in the scope of the research focus. The findings are reconceptualized as design suggestions for clinical practice and physiotherapy education in response to the second research question. Lastly, the researcher added personal suggestions for further studies.

# CHAPTER 2

# LITERATURE REVIEW

Among the current health problems, respiratory diseases affect many of the world's population. According to the report of the World Health Organization, more than 1 billion people worldwide suffer from either acute or chronic respiratory conditions (Cruz, 2007). Although most of these ailments are caused by air pollution and tobacco products that harm lung health (World Health Organization, 2008), chronic respiratory diseases caused by genetic mutations also affect more than 500 million people worldwide.

Among these respiratory diseases, those with a higher number of patients, such as asthma, COPD, pneumonia, and bronchiectasis, are more well-known worldwide. However, people with rare genetic diseases such as cystic fibrosis also have similar respiratory problems, but most people do not know them due to the small number of patients. There are currently more than 100,000 people living with cystic fibrosis worldwide (Stephenson et al., 2017).

The secretions in the lungs protect the lungs against pollutants and the risk of infection by capturing airborne particles that can enter the body through the respiratory tract. (Mauroy et al., 2015) In some chronic respiratory diseases, unlike healthy individuals, the mucus layer in the lungs is secreted in a thick and sticky way. This situation causes secretion obstruction in the lungs of patients. (Fahy & Dickey, 2010). Figure 2.1 represents the mucus layer accumulated in the airways.

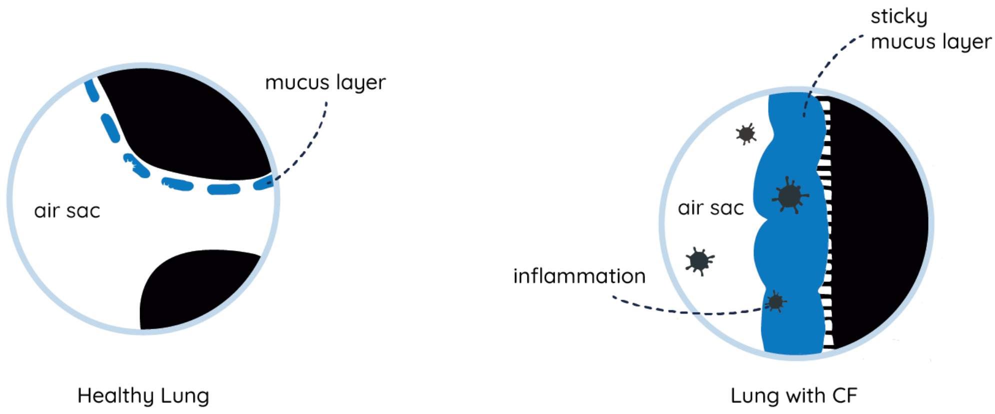


Figure 2.1. Airway mucus comparison between a healthy individual and a Cystic Fibrosis patient. Adapted from, (https://www.cysticfibrosis.org.uk/what-is-cystic-fibrosis)

In healthy individuals, mucociliary clearance and cough mechanisms are autonomous defense methods used by the body to prevent secretion obstruction. In people with respiratory tract diseases, accumulation in the airways cannot be prevented due to the cilia and mucociliary clearance structure not working correctly (Chatwin et al., 2018).

Secretion obstruction prevents people from breathing easily during the day and prevents oxygen from being taken into the cell due to the mucus layer covering the alveoli. This thick and sticky mucus makes it difficult for patients to breathe easily during the day. It prevents oxygen from being taken into the cell due to the mucus layer covering the alveoli (Chatwin et al., 2018). Figure 2.2 shows how the mucus layer prevents oxygen passage into the cells.


Figure 2.2.Preventing the passage of oxygen into the cell. Adapted from, (https://www.bridgesclinic.co.uk/procedures/pulmonary-fibrosis-interstitial-lung-disease-ild/)

Excretion management of bronchial secretion is a significant problem in a wide range of patients, from respiratory diseases (e.g., COPD, bronchiectasis, cystic fibrosis) to neuromuscular diseases (e.g., ALS, SMA-Type I). The term airway clearance techniques (ACTs) is a definition that includes different methods used for eliminating secretions. ACTs consist of therapies, techniques, and devices for managing bronchial obstruction, such as oscillating positive expiratory pressure (OPEP), active cycle breathing (ACBT), positive expiratory pressure (PEP), high-frequency chest wall oscillation (HFCWO), and manual chest physiotherapy method (Belli et al., 2021).

However, according to research, manual chest physiotherapy has been patients' least preferred Airway Clearance Technique (ACT) as it is uncomfortable and socially limiting and requires a caregiver to administer the treatment (McIlwaine et al., 2010; Sontag et al., 2010). Moreover, according to Eurostat healthcare personnel statistics, 597 000 physiotherapists were working in the EU, equivalent to an average of 133 physiotherapists per 100 000 inhabitants. This number drops to less than one physiotherapist for every 1000 patients in Turkey (Eurostat, 2018).

Table 2.1. Adapted from Eurostat's Healthcare personnel statistics - dentists, pharmacists, and physiotherapists report.

| Physiotherapists | Number | Per 100 000 inhabitants |
|---|---|---|
| European Union | 596 910 | 133.5 |
| Türkiye | 6 588 | 7.9 |

Given these reasons, increasing the number of qualified personnel who can apply manual chest physiotherapy treatment to patients is necessary. Improving students' education in institutions is essential to ensure this situation.

## 2.1 Understanding of Medical Education

Entry-level education provides healthcare students to acquire the necessary knowledge, skills, and behaviors before taking on responsibilities in professional life. Chipchase et al. (2012) stated that it is an essential determinant for students to work safely and competently.

In the traditional education system, the lessons are in a format that includes one-sided information transfer in which the teacher plays an active role, and the students are listeners. This system is based on listening to the lectures, taking notes, and using the theoretical knowledge in the exams to be successful. Unfortunately, this situation is unsuitable for health professional education, which requires a practical application (Frenk et al., 2010). Thus, the theoretical knowledge given in the health field courses should be supported in a clinical environment.

At this point, the clinical education program is at the core of entry-level education, bringing together clinical providers and universities. This inter-institutional collaboration aims to provide opportunities for students to develop knowledge and skills with the guidance of qualified practitioners (Chipchase et al., 2004). Kilminster & Jolly (2000), Bryant et al. (2003), and Spencer (2003) comment that it is an educational method that offers students the opportunity to actively use and integrate their theoretical and practical knowledge in a social environment.

On the other hand, clinical training has its limitations and challenges. Due to the growing number of students, clinical facilities and educators must have the skills to manage large numbers of students seeking an interactive patient experience. Moreover, the clinician may not devote time to training each student. On the other hand, patients are increasingly concerned about students ‘practicing’ on them (Okuda et al., 2009).

These key points show that healthcare professional students' access to patients is increasingly limited, so new clinical teaching methods must be considered to prepare students for clinical practice.

## 2.2 Simulation as an Educational Tool

In the traditional form of education, where there is no interaction between educators and students, basic science concepts and treatment management knowledge transfer are based on problem-based learning. On the other hand, simulation-based education aims to teach these concepts interactively using motor skills (Okuda et al., 2009). The effect of the interaction on the concentration is shown in Figure 2.3.

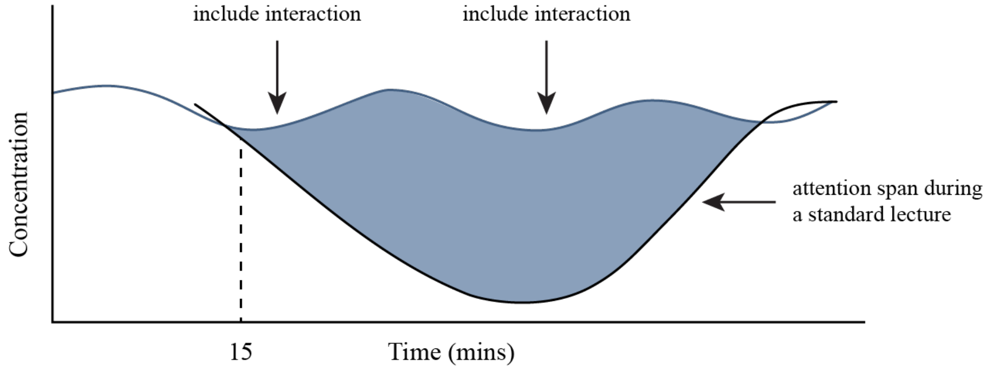


Figure 2.3. Audience concentration during a standard lecture with and without interaction. Source: Higher Education Academy Engineering Subject Centre

Many studies have shown that simulation is an effective evaluation tool in medical education. Simulation is commonly used as an assessment tool to identify the gaps between medical students' theoretical knowledge and practical application in patient treatment management (Young et al., 2007).

In addition to being a valuable assessment tool, simulation has gained widespread acceptance in medical education, including medicine, dentistry, basic sciences, nursing, and other allied health specialists (Cook et al., 2011). Some of the most common reasons simulations have gained popularity include creating a safe environment, allowing the desired number of patient problems, the reusability of content, and easing simulation critical cases (Gaba et al., 2001).

Simulation or Simulation-Based-Learning (SBL) also has an essential role in students' psychological and emotional development. According to studies, high levels of stress and anxiety are typical during the academic life of medical students. Evidence suggests that stress during undergraduate education can lead to psychological or emotional disruption in professional life. These problems may cause consequences that will affect the quality of patient care (Rosal et al., 1997).

In studies conducted with medical students, it has been observed that students generally find the transition to the clinical environment highly stressful. Moreover, many students think they need more training in history taking, physical examination, diagnosis, and treatment (Okuda et al., 2009).

According to focus group interviews of Delany & Bragge (2009), the student who took six weeks of clinical placement training realized that the learning process involved more than just applying factual knowledge to the patient:

> "It isn't just black and white. You think it's really black and white and there are so many patients where there are different things that you need to do that are different to what the textbooks would say. And then there are different things you need to do depending on which supervisor you talk to as well. So, it's just sort of making up your mind, using the theory and enough so that it's safe and that's how you're doing to provide the treatment but also being able to use your common sense." ( p. e405)

At this point, simulation-based education acts as a bridge to overcome these deficiencies.

### 2.2.1 Standardised Patients

Simulation, as mentioned before, replaces real patient encounters with standardized patients or technologies replicating the clinical scenario.

Another method of case-based teaching and learning is standardised patient (SP) cases. SPs are individuals used to portray a particular patient role in a case scenario designed by faculties for students (O'Connor et al., 1999; Stroud et al., 1999).

'Standardised' patients were first introduced in the 1960s by Barrows & Abrahamson (Barrows & Abrahamson, 1964). Although actual patients were consistently trained to represent their problems for teaching and assessment purposes, today, they are ordinary people trained to simulate a patient's illness (Barrows, 1993).

On the other hand, an unprepared student can create safety risks for the patient and put more strain on the clinical educator (Chipchase et al., 2012). So, using standardized patients allows for immediate feedback while allowing students to learn and practice formative skills in a controlled and less threatening environment (Becker et al., 2006).

### 2.2.2 The Mannequin Simulator

One of the earliest simulators, a mannequin called the Resusci Anne, was developed in 1965 by the Laerdal Corporation to train mouth-to-mouth resuscitation protocols (Cooper & Taqueti, 2008). This prototype focused on airway management and basic life support techniques and pioneered the next generation of high-tech simulators. In Figure 2.4, Asmund Laerdal shows the use of the resusci Anne mannequin.

Figure 2.4. Asmund Laerdal with the CPR doll Resusci Anne. (https://emsmuseum.org/collections/archives/education-simulation-and-training/resusci-annie/)

As medical education became more demanding, the need for safe and effective training solutions catalyzed the development of medical simulators. (Datta et al., 2012).

Simulators range from low-tech, simple plastic infant, toddler, or adult mannequins to realistic, high-tech versions. The medical education process integrated into the simulators can be handled at different levels. These levels can be used to teach and evaluate three levels, from basic individual skills through complex individual skills to multi-dimensional teamwork skills. An example of the initial skill level is how to position the stethoscope for proper cardiac examination. An example of the second skill level would be performing a cardiac examination and interpreting findings. For the third skill, an example is a scenario of how to do teamwork to manage a heart attack patient (Lane et al., 2001).

High-quality simulation mannequins can simulate physical feedback such as heart and lung sounds, sweating, and vital changes such as blood pressure, pulse, and breathing (Okuda et al., 2009). However, despite the continuous development of new simulators in medical education, the medical field lags behind in the aerospace industry and the armed forces in terms of complex simulation and focused information retrieval (Lane et al., 2001).

Design projects that have the technology level in the above-mentioned fields and will be developed considering simulation education in medicine will be valuable studies that can meet this need.

### 2.2.3 Designing a Simulation Activity

Battista & Nestel (2018) suggest that because simulations can be very complex and require more resources, designing a simulation may take longer than developing a course content or case study. Starting the simulation design process well before the expected start of the curriculum will ensure sufficient time to evaluate each design step and consult subject matter experts. These efforts will help create a higher-quality simulation (Battista & Nestel, 2018).

A pre-structured approach is used in designing application processes for a simulation design. For this process, Wiggins & Tighe (2005, p.21) recommended the "backward design" that starts with establishing goals and objectives and continues with determining evaluation methods. The final stage of this 3-stage process is the improvement of the designed activities.

The first step is to set goals for general topics such as patient assessment, medication management, or team communication. Afterward, more specific goals are focused on, such as calculating drug doses for patient-specific or ensuring effective communication between team members in critical cases. Moreover, the simulation activity is designed so that the participants exhibit and evaluate the targeted behaviors. Finally, the simulation activity is designed so the participants can implement the targeted behaviors and be evaluated by the trainers (Hagler & Wilson, 2013). Figure 2.5 shows the recommended steps to develop a simulation-based competency assessment.

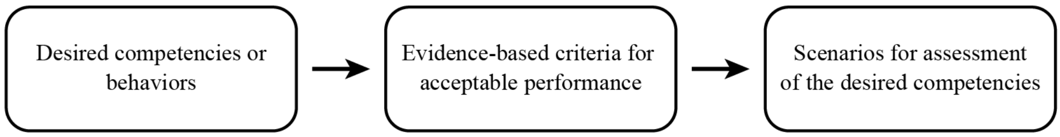


Figure 2.5. Steps of backward design to develop simulation-based competency assessment.

Another critical point is that the evaluation in the designed simulation is objective and reliable. The reliability here is to ensure that the evaluation is consistent when the simulation is used at different times and by different users (Reynolds, Livingston, & Wilson, 2009).

The scenario of a well-developed simulation is designed according to the competency to be evaluated. The training mannequin will be suitable for the scenario in simulation system designs where a physical medical method is taught. This way, psychomotor skills can be evaluated (Waxman, 2010).

During the development of these scenarios, Decker et al. (2011) recommend that experts may test scenarios with simulation prototypes before implementation. In this way, the parts that require revision can be determined better.

### 2.3 Respiratory Physiotherapy

Physiotherapy is essential to patient management in respiratory intensive care units (Society of Critical Care Medicine, 1999; Ferdinande, 1997). The most critical application is to increase the patient's respiratory capacity and restore physical independence. For this purpose, cost-effective treatment methods are applied to eliminate the patient's dependence on the ventilator, prevent hospitalization, and improve the patient's quality of life (Clini & Ambrosino, 2005).

Respiratory physiotherapy includes various methods and devices that help improve the respiratory function of patients with respiratory disease. These devices are Positive Expiratory Pressure (PEP), High-Frequency Chest Wall Oscillation (HFCWO), Oral High-Frequency Oscillation, Intrapulmonary Percussive Ventilation, and Incentive Spirometry (Hristara-Papadopoulou, Tsanakas, Diomou, et al., 2008). In addition to these devices, there are also manual methods applied by physiotherapists.

Manual methods are generally preferred in physiotherapy treatments applied to respiratory patients in the UK. These manual methods are thought to simulate coughing to push mucus from the airways into the large airways for removal from the body (McCarren & Alison, 2006). The healthcare worker imitates the cough by 'chest wall vibrations' applied to the patient.

## 2.4 Manual Chest Physiotherapy

Chest physiotherapy is one of the most frequently performed interventions in intensive care areas. This airway clearance method is based on external maneuvers on the chest, which are applied to patients by respiratory physiotherapists or patients' relatives. Mauroy et al. (2015, p. 2) define manual chest physiotherapy as:

> "It relies on a basic concept: the pressures the practitioner applies on the chest transmit into the lungs and deform the bronchi. Bronchi's volume changes create an airflow inside the lung, and the mechanical constraints applied on the secretions by the airflow affect the secretions and have the potential to induce motion."

Manual chest physiotherapy applied to the patient by the parent is shown in Figure 2.6.

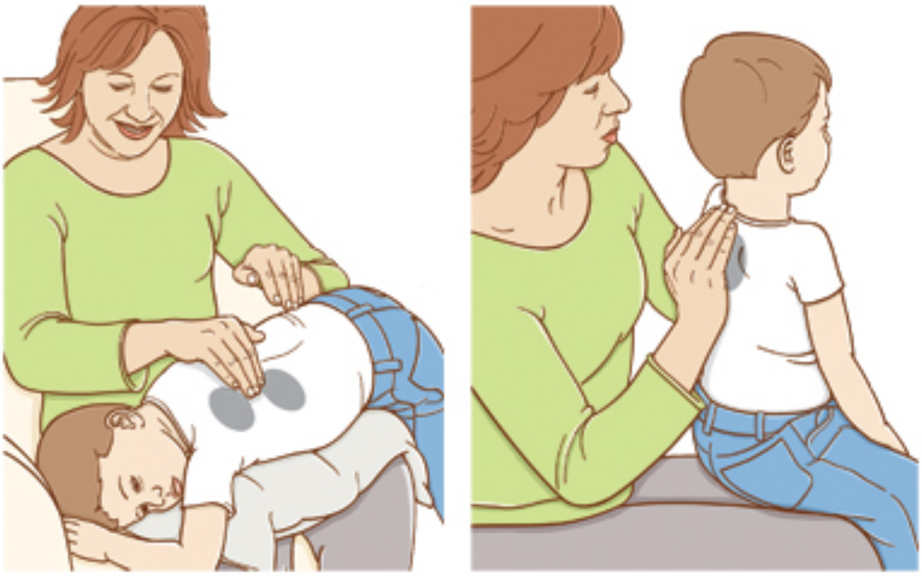

Figure 2.6. Application of manual chest physiotherapy.
(https://www.snehphysiotherapy.com/chest-physiotherapy)

Physiotherapists may use various techniques during manual chest physiotherapy sessions to facilitate secretion clearance. Percussion is one of these techniques in that a downward force is applied rhythmically to the patient's thorax segments(s) of the lung. It is thought that the air trapped in the 'cupped hand' creates an energy wave in the respiratory tract. This energy transfer increases secretion and thus positively affects airway cleaning (Shapiro et al., 1991). The form in which the physiotherapist's hand should be during the physiotherapy application is shown in Figure 2.7.

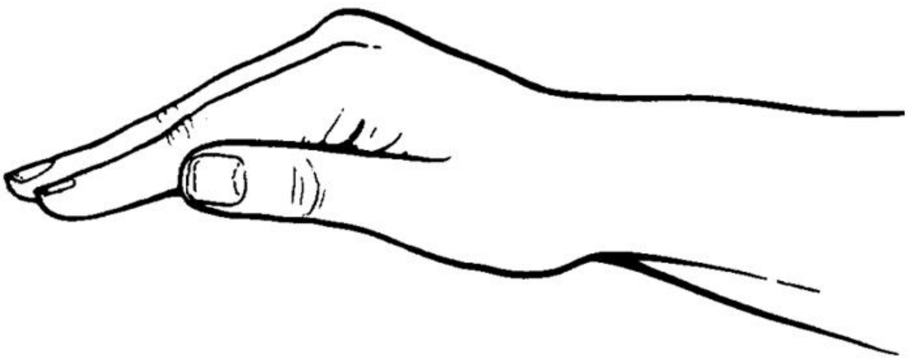

Figure 2.7. The cupped hand curves to the chest wall and traps a cushion of air to soften the clapping. (https://www.cff.org/managing-cf/chest-physical-therapy)

Another technique, vibration, consists of compression and simultaneous oscillation movements, which are initiated at the end of inspiration and continue to be applied throughout expiration. The vibration applied by the physiotherapist using her/his hands and fingers compresses the thorax and supports increasing expiratory flow (McCarren et al., 2006b). Figure 2.8 explains how the vibration method is applied to the patient.

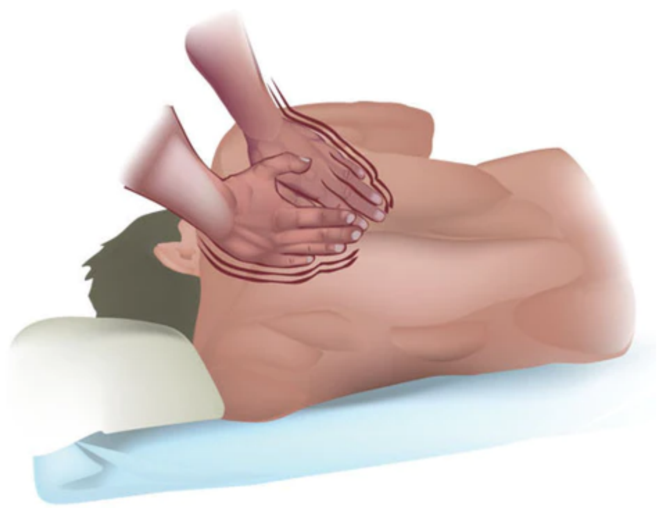

Figure 2.8. Vibration gently shakes the mucus so it can move into the larger airways (https://blog.lptmedical.com/16-mucus-clearing-techniques-that-alleviate-shortness-of-breath)

The manual chest physiotherapy method is a passive treatment, and an assistant is needed for its application. Therefore, this method may be more suitable for patients who can not do their treatment (Lee et al., 2016).

## 2.5 Research Through Design (RtD)

One point that differentiates the design discipline from other disciplines is that designers work on wicked problems rather than well-defined ones (Cross, 2001). Therefore, the design discipline requires 'designerly' ways of thinking and acting (Cross, 2001, p.54) and needs research approaches specific to the design discipline (Schön, 1991). At the same time, the scale of design problems and the diversity of stakeholders require working with people from different disciplines in a transdisciplinary project (Brown, 2009).

Research through design is a research method that applied research aims to connect design outcomes to advance theory while linking theory and practice (Dalsgaard & Dindler, 2014). Thus, it is recommended for transdisciplinary design works where identifying and controlling design dynamics is complex (Stolterman & Wiberg, 2010).

In projects involving different disciplines, it is difficult for researchers to create concepts that can be fully understood by stakeholders (Gaziulusoy & Boyle, 2013). At this point, the research through design approach includes a process in which stakeholders and professionals related to the research subject is included. This approach differs from other methods as it not only adds the user to the research process but also leads to new ideas and solutions.

One of the common methods used to involve stakeholders in the process is prototyping. Prototypes, whether props or fully functional devices, play an important role at research through design in answering research questions. However, these prototypes were produced for research purposes (Zimmerman, Forlizzi, & Evenson, 2007) and should not be confused with products for the consumer market. The roles of these prototypes "as vehicles for research about, for and through design" is manifold (Wensveen & Matthews, 2014, p. 262).

Moreover, as Gunn & Donovan (2012) stated, the prototype's role in collaborative design practices is often to support individuals to imagine, discuss, and shape future versions during the development process. Designing in this sense is a kind of stabilizing process in which future versions of the outcome are imagined and realized. In RtD approaches, this stabilizing character of prototyping is expressed in helping to reach a kind of consensus between designers and non-designers (Sanders & Stappers, 2014).

One way to use prototypes is to support a process of design activity and its outcome about what worked and what did not. While serving this function, artifacts are primarily used in evaluation processes. In Keller's (2005) Cabinet study (Figure 2.9), the prototype series aims to support collecting and editing images for design inspiration. Much of the learning in this project occurred during the making of prototypes has been through explanations and discussions with lab visitors during the making of prototypes and discussions with lab visitors, rather than through formal experiments.

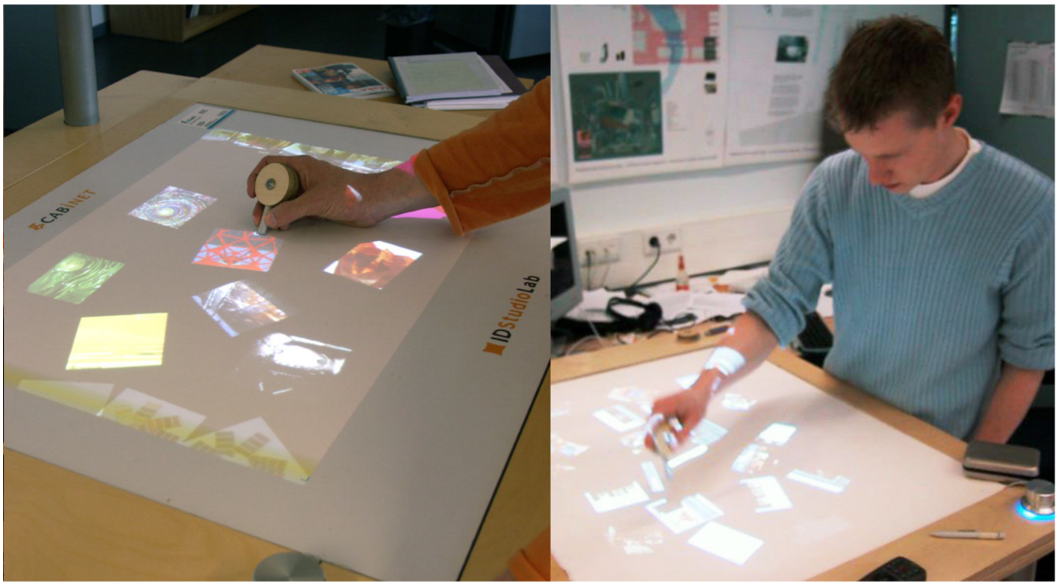


Figure 2.9. Testing how to collect and organize images for design inspiration (Keller, 2005).

Archer & Roberts (1992, p. 34) defines the contribution of artifacts in research through design as below:

> " The [mind's eye] image is usually externalised through models and simulations, such as drawings, diagrams, mock-ups, prototypes and, of course, where appropriate, a language and notion, or it can be embodied in the construction of or the enactment of the emerging responses. The externalisation capture and make communicable the concepts modelled. "

These approaches make research through design suitable for this thesis because the designer/researcher has a project that needs to work in harmony with physiotherapy instructors and students. In addition, it prevents the skills of designers from becoming dull in the research process, as it enables researchers to use their design skills actively throughout the research. Finally, using prototypes to convey design ideas and get feedback from stakeholders will be useful in the field research of the thesis process.

## 2.6 Summary and Discussion

This section examined respiratory physiotherapy and medical training in the health and design literature. Respiratory system diseases are a significant cause of disease worldwide and are becoming increasingly important as a cause of mortality and morbidity (WHO, 2004). Treating these patients is one of the main problems encountered in a broad spectrum ranging from respiratory to neuromuscular disorders. As mentioned previously, the term airway clearance techniques (ACTs) refers to various strategies used to manage these patients for airway clearance (Lee, Burge & Holland, 2015).

Currently, physiotherapists are actively involved in treating patients (Clini & Ambrosino, 2005). However, the increase in the number of physiotherapy students and the difficulties in accessing real patients for clinical training reduce the quality of education (Okuda et al., 2009). This situation causes the need for alternative training methods such as simulation system design and mannequins (Lane et al., 2001). People may consider it absurd to complete their education without contacting the patient directly. However, medical schools are striving to maximize this, and teachers are trying to achieve it (Spencer, McKimm & Symons, 2018). The clinical practice stakeholders in health education and the benefits of the process to the students are shown in Figure 2.10.

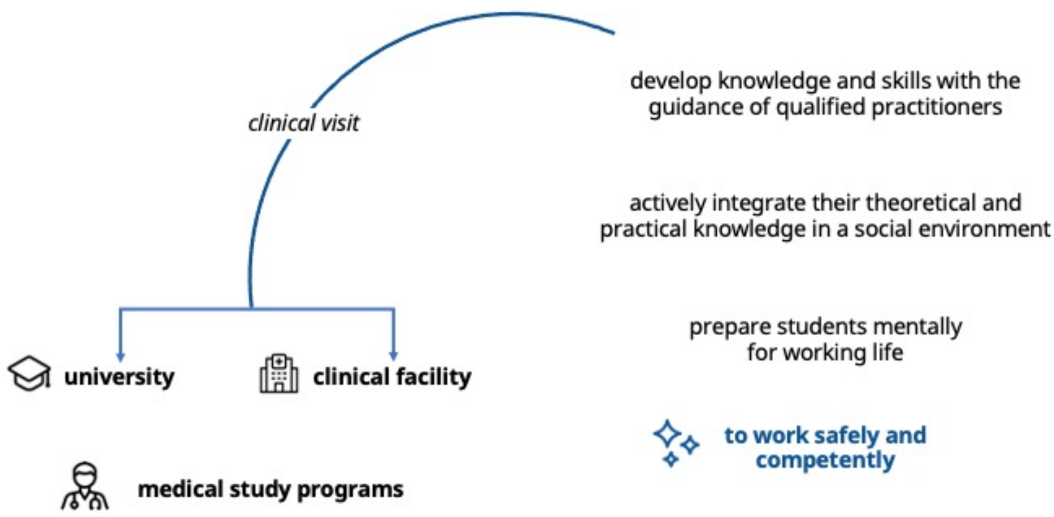


Figure 2.10. Stakeholders and benefits of clinical practice

It has been stated in the above studies that there are not enough products related to clinical practice in physiotherapy education. In order to provide a solution to this need, it would be beneficial to conduct a study that will help designers, especially in physiotherapy training, explain the process of designing clinical application products and make design suggestions.

Moreover, the research through design approach will be actively used in the thesis process, so that designers will better understand this approach and it will be a helpful resource for designers to use this method in their research processes.

# CHAPTER 3

# METHODOLOGY

As mentioned in the introduction chapter, this thesis aims to explore the practice of design throughout the product design process and to make suggestions to designers and design students who want to develop an interactive educational product in the health field to improve their perspectives during the idea and concept generation stages.

Thus, the study should first reveal the current state of physiotherapy education from the perspectives of professional physiotherapists and students so that potential improvements and requirements can be identified for designing the interaction between users and the product.

In this context, it is essential to reveal how designers approach the process of designing educational products to be used in physiotherapy and how they incorporate them into holistic design processes. In this study, the outputs obtained from the interview with the expert and the internal experiences of the researcher during the design processes should also be investigated. Thus, a qualitative approach was adopted in the research, focusing on revealing the inner experiences of the participants and how the outputs for the research topic were shaped.

Moreover, this study also attempts to offer suggestions that can be useful to both professional designers and students in generating ideas in the field of health education and designing the interaction between users and products.

On this basis, the research through design approach has been adopted to reveal the outputs of the research and product development process and carry out the process appropriately. A methodology is used in which a conceptual product is developed at the beginning of the study, and refinement is made through several rounds of user research and design development.

Stolterman & Wiberg (2010) recommend research through design approach for situations such as interactive designs where the determination and control of design dynamics are complex. Moreover, Archer (1995, p. 118) defines research through design as below:

> "… gaining knowledge through the process of designing, building and testing highly experiential prototypes."

Therefore, this study is based on designing a conceptual product, and this product development process is in line with data from people who participated in the field research.

The training system design (Physiocircle) is explained in detail in the following thesis sections. Although this physiotherapy training system design involves a product development process that resulted from collaborative work and research, there were other purposes. At the end of this process, it is aimed to reveal the knowledge and experience that will guide the designers in the design process in the field of medical education.

Figure 3.1 represents the general research phases. These stages include a literature review and field research. In the first stage, secondary sources were determined by examining the related publications, and a literature search was done by using these sources. In the second stage, user evaluations were taken about the Physiocircle V1-V2, and improvements were made in the design.

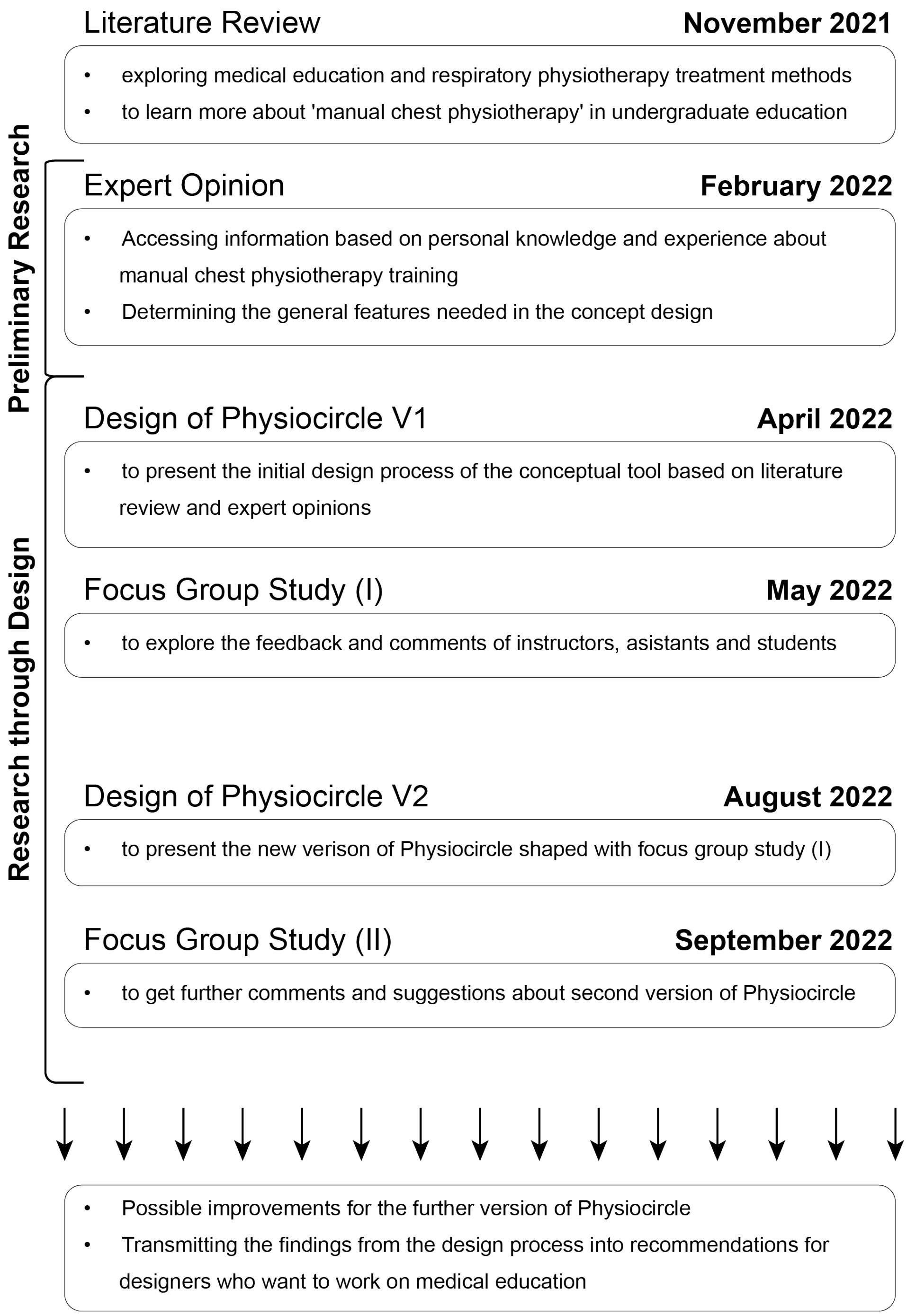


Figure 3.1. Overview of research stages

## 3.1 Preliminary Research: Expert Interview

The expert interview is accepted as one of the most appropriate obtaining method for collecting, analyzing, and evaluating information in the research process (Bogner, Littig & Menz, 2009; Lewthwaite & Nind, 2016).

One of the important points about this method is that the expert has sufficient knowledge about the research subject. In this method, the researcher should be fully responsible for the experts' competence and suitability for research (Hoffmann et al., 2009). Similarly, Meuser & Nagel (2009) suggest that an expert should be selected as a highly qualified and open-minded individual with higher scores in the subject area than the average participant.

Unlike large-scale surveys, where respondents are mostly anonymous, identity is known in expert interviews. During the expert interview, a researcher can learn about the unique and profound knowledge and experiences that an expert has gained throughout his or her life (Iriste & Katane, 2018).

For these reasons, it would be helpful to get an opinion from an expert who works as a trainer in physiotherapy. Moreover, using the information from the literature research to design a concept product alone is not enough to understand user needs.

In this study, a semi-structured interview was planned to gather more in-depth information about the knowledge and experience of participants who met the qualifications mentioned earlier. Semi-structured interviews are generally conversational activities that include closed and open-ended questions using 'why' or 'how' questions (Adams, 2015). Adams (2015) also states that interviewees selected for semi-structured interviews should be sensitive, intelligent, able to think quickly, and knowledgeable about important issues. The interview guide was prepared by considering the existing literature and research questions.

The first part of the question aims to learn more from experts about manual chest physiotherapy. In this section, additional literature information based on the participants' personal experiences was obtained through the questions asked to the participants about manual chest physiotherapy.

In the second part of the question, questions were asked by focusing on the training on manual chest physiotherapy given at the undergraduate level. In addition to gaining an idea about the current education system's functioning, the instructors' motivations, unique training methods, needs, and obstacles were discussed.

One expert interview was held with a professor working in respiratory physiotherapy for more than 25 years at Hacettepe University Faculty of Physical Therapy and Rehabilitation. Semi-structured questions were used in the face-to-face interview (Appendix A).

An interview conducted with the expert confirmed the theoretical information in the literature and helped realize the overlooked information. It also helped to identify user needs as she/he shared knowledge and experiences during the interview. Expert opinions in this direction contributed to the design of the first version training product.

## 3.2 Field Research

The field research for developing a physiotherapy training system was planned in a two-stage structure. In the first stage, detailed information about the research topic was obtained using the sources found in the literature review. In addition, information about the procedure was collected during the interview with an expert working as an instructor in respiratory physiotherapy. The first version of the physiotherapy training product was designed in light of the information obtained from this research and interview. The first version of Physiocircle was used actively in focus group studies, and it was planned to convey the feedback and ideas of the participants effectively. Thus, the interaction of the users with Physiocircle V1 could be observed, and feedback from the users could be obtained.

Accordingly, a focus group study was conducted in the first stage using PhysioCircle V1. This focus group study included all possible user types, such as instructors, assistants, and students. In this way, the first version was evaluated from the perspective of different user types. The design details of the second version are based on the insights from participants' feedback at this stage.

In the second stage, a focus group study was conducted again using PhysioCircle V2. The people who were in the first stage were used as participants again. Users who know the first version can better observe the changes and improvements in the second version. In addition, as they take an active role in the product development process, they will have a greater sense of belonging in the development process and will be willing to contribute. During the field research, a dynamic setup was created in which ideas and outputs supported each other using research through design.

### 3.2.1 Design of the Educational Training System, Physiocircle (V1-V2)

The reason for transforming the information gathered from the literature review and expert opinions into a concept design before starting the field study is to get the optimum contribution from the participants in the product development process. In addition, the detailed information about the design and development processes of different product versions in the following sections ensures that the designers have information about the stages of a product design for health education purposes.

As a result of the research, expert opinion and focus group studies conducted throughout the thesis determined that the solution should include an integrated digital application and a physical product. For this reason, the developed design is defined as an "educational training system."

Two versions of the Physiocircle system were designed throughout the process. Both versions include a physiotherapy vest (physical product) and tablet and desktop applications (digital products) integrated with the vest. Adobe Illustrator program was used for the design and development processes of the physical product, and professional sewing support was received for the production of the created wearable vest design. Adobe XD program was used for designing digital products and user testing. In the first version, focus group discussions were conducted over this program, and feedback was received. In the second version, professional support was received for frontend and backend coding of mobile applications (tablet and desktop). In this way, people participating in the focus group meeting could test the education system with digital applications that work in all functions. The purpose of developing an interactive prototype helped get detailed feedback from participants on functionality and user experience. During the focus group sessions, Physiocircle V1-V2 was introduced to the participants, and their interactions with the system design were observed without guidance. Considering the feedback and comments from users, suggestions that will help designers who want to design a training system in the field of physiotherapy have been added to the conclusion chapter.

## 3.3 Data Collection Techniques

Two main data collection techniques were used in the field research. These techniques are semi-structured interview to get expert opinions and focus group studies. The semi-structured interview was conducted with a respiratory physiotherapy instructor with more than 25 years of experience. The session was recorded and transcribed. Later, the obtained data were analyzed. Before starting the study, necessary permission was obtained from the Middle East Technical University Applied Ethics Research Center with the code 0450-ODTUIAEK-2022.

### 3.3.1 Focus Group Studies

The focus group studies aimed to explore the perspectives of eight participants (three instructors, three assistants, and two students) on the Physiocircle system design and gather feedback for new product releases. As the participants in the focus group are professors, assistants, and students, a dynamic environment has been created that includes different types of users. This way, the needs and comments of the user not discovered in the expert interview were determined using the concept product.

Focus group studies were conducted face-to-face at Hacettepe University Faculty of Physical Therapy and Rehabilitation. At the end of the expert interview, the contact information of the instructors, assistants, and students who could participate in the focus group study was requested. A study invitation was sent via e-mail, and participation approvals were received. Before the focus groups, prototype production of Physiocircle was made. This way, the participants could express their ideas and opinions using the prototype. The focus group studies, repeated twice, lasted an average of two hours, and the outputs obtained from the interview were noted and analyzed. The Physiocircle was revised by analyzing the information obtained. The same participants were invited for both focus group studies. In this way, the participants could better observe the change between the versions of Physiocircle and contribute more with a sense of commitment to the process.

## 3.4 Sampling

Sampling was used to determine the interviewee and focus group participants. In the field study, convenience sampling was used, in which the participants were selected according to their suitability (Frey, 2018). For this reason, a sampling was made for an interview among professional physiotherapists in physical therapy and rehabilitation faculties. Care was taken to ensure that the selected interviewees were experts in respiratory physiotherapy. The decision to interview two respiratory physiotherapists was made to strike a balance regarding adequate exploration and practicality of the subject.

While selecting the focus group participants, two main criteria were considered: Having an undergraduate education in manual chest physiotherapy or taking part in classes as an instructor. In this context, focus group studies were carried out with the participation of three instructors, three assistants, and two students from Hacettepe University Physical Therapy and Rehabilitation Faculty.

### 3.5 Data Analysis: Affinity Diagram

The Affinity Diagram is a tool that allows for the visual organization and analysis of large amounts of data, allowing classification into common themes. (Gkatzidou et al., 2021). Therefore, an affinity diagram is an efficient method for categorizing data and revealing relationships between them.

Within the scope of this study, the Affinity Diagram was used to combine the data collected from the interviewees with the researcher's notes and to determine the relationships between coding and categories.

An affinity diagram was created by integrating the information and codes collected from the participants and the researcher's notes. The Affinity Diagram table in Miro, an online working tool, was used for this process. The codes obtained in this process were categorized, and each category was given a color code. An example of the color-labeled coding structure is shown in Figure 3.2.

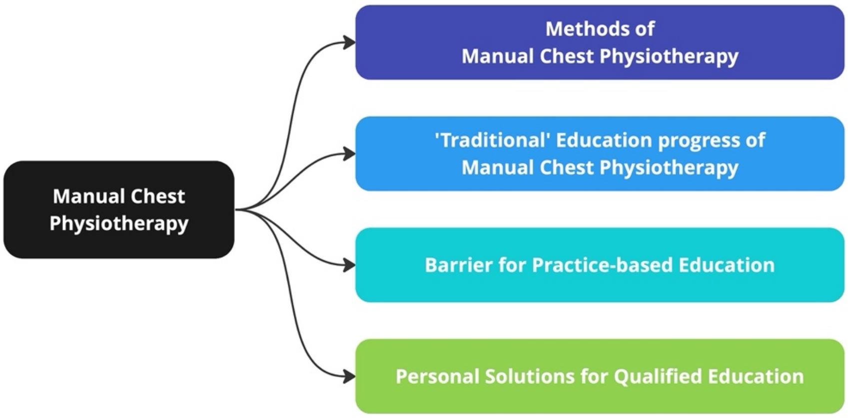


Figure 3.2. Color-coded structure from Affinity Map

As seen in Figure 3.3., the researcher's notes were associated with the participants' quotes and the codes from the code structure.

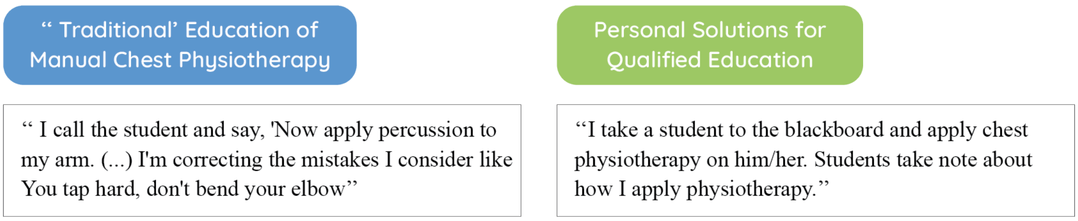


Figure 3.3. Section from Affinity Diagram

The raw data obtained in the field studies with the focus group were recorded as interview notes using the Confluence online meeting notes recording tool. Afterward, these data were added to the relevant categories in the previously created affinity diagram. The newly discovered outputs not included in the coding have been added to the map as a new title.

It has been understood that the Affinity diagram is a method to help designers find the inspiration they seek to develop a product to be used in medical education. This categorization of the raw data collected during the interview and revealing the relationship between them guided the design decisions. In addition, the participants' personal experiences, motivations, concerns, and needs enrich the guide that emerged in this thesis process.

# CHAPTER 4

# RESEARCH THROUGH DESIGN – PART 1

Research through design approach supported the researcher in generating insights connecting knowledge from different disciplines and levels. It also supported the researcher by providing a holistic understanding of a complex research area. Therefore, as with interdisciplinary projects, it may be more embraced by researchers who conduct research with complex research phenomena. Figure 4.1 shows the stages of research through design used in the field research.

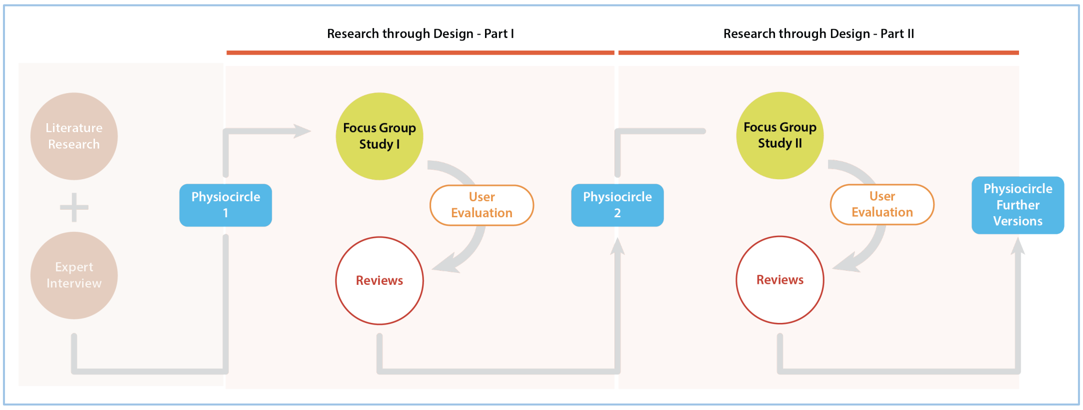


Figure 4.1. The research through design process followed and the relationships between components

As detailed in the methodology section, the field research of this thesis is to develop a product design (Physiocircle V1, V2) to be used for clinical practice and to create forward-looking design suggestions with the data collected in the focus group studies.

Accordingly, this chapter will discuss the rationale for using the health education literature and the expert interview results to create a first design proposal for a product to be developed for education in physiotherapy.

After the “Determination of the Initial Design Proposal” section is presented, the “Physiocircle Design: V1” section describes the first version of the training product content. In the last part of this section, the results of the focus group study are presented and analyzed. Thus, new design ideas for Physiocircle V2 are determined.

## 4.1 Determination of Initial Design Proposal

As mentioned in the previous chapters, health education is discussed in the context of respiratory physiotherapy. As a result of the research, it has been noticed that with the developing technology, simulation dummies have started to be preferred more in health education. Simulation mannequins are widely used for undergraduate education in different professions, such as medicine, nursing, and dentistry. However, during the literature review, it was determined that there is a need for training products specially developed for respiratory physiotherapy to increase the quality of education. The lack of educational training system products in physiotherapy education was also confirmed during the expert interview.

For these reasons, literature research and expert interview were conducted in respiratory physiotherapy. The manual chest physiotherapy method has been studied in depth in this field. Manual chest physiotherapy is a treatment that a physical therapist gives to people with respiratory conditions to remove mucus from their lungs. During this treatment, combinations created by different methods, such as clapping, shaking, and vibration, are applied to the patient by the physiotherapist.

Figure 4.2 shows the physiotherapist's percussion method applied to the patient during manual chest physiotherapy.

Figure 4.2. Manual Chest Physiotherapy (https://greenlifephysiotherapy.com/services/cardiopulmonary-physiotherapy/)

In addition, since each patient's disease is different from the other, the physiotherapist should apply personalized manual chest physiotherapy. This situation requires physiotherapists to undergo training that combines theoretical and practical knowledge. Accordingly, it has been determined that there is a need for a digital application where students can learn theoretical knowledge and a simulation mannequin where they can improve their hand skills by practicing it. Therefore, it was decided that the training system should include a physical simulation training vest and integrated digital applications.

The general design of the training vest was determined in light of the information obtained during the literature review. Accordingly, physiotherapy is applied in ten lung regions (Figure 4.3).

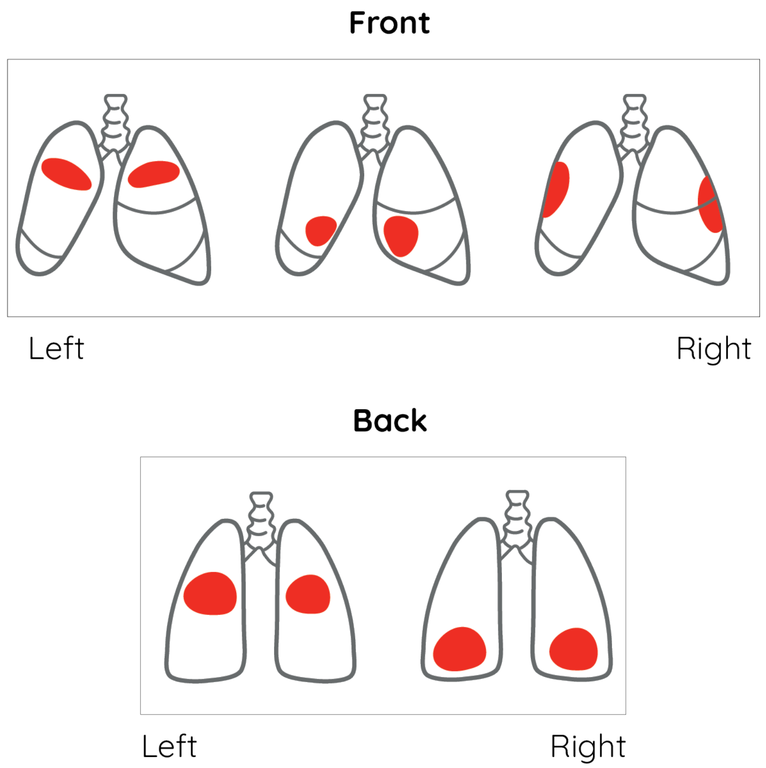


Figure 4.3. Chest Physiotherapy Zones

The vest design was determined concerning these regions. In addition, detailed information about the current education system was explained in the expert interview. During this meeting, theoretical knowledge is emphasized in manual chest physiotherapy training at the undergraduate level. The practical part of the common lectures is in the format that the student applies chest physiotherapy to instructors or other students. This situation prevents the delivery of effective and followable education on chest physiotherapy training for students and instructors.

Another important point mentioned in the expert interview is that student follow-up is difficult due to the growing number of students. It is planned to eliminate this problem with the desktop application designed for instructors to follow each student's chest physiotherapy progress during the semester.

Moreover, there is no general standardization for intensity, frequency, and duration data applied at manual chest physiotherapy for correct and effective treatment. For this reason, students cannot be given feedback on the physiotherapy they apply. To eliminate this deficiency, a force sensor was used to monitor the force, frequency, and duration data in the training vest to be designed.

## 4.2 Design and Production of the 'Physiocircle - V1'

As described in detail in the previous chapters, this thesis aims to convey the knowledge and experience of the researcher to help industrial designers who will design health education products to carry out the development process effectively.

The training product concept (Physiocircle - V1) has been developed to enable healthcare professionals to interact with the product and effectively express their feelings and comments. The information from the literature search and the personal experience and comments obtained in the expert interview helped make the design decisions for the first version of the training system design. The first version's design decisions and features, including physical and digital design elements, will be explained in detail in this section.

The physical parts of the Physiocircle consist of a physiotherapy manikin and a vest. Since it would not be possible to design and manufacture adult mannequins in the thesis process, ready-made products were used. Among the training mannequins on the market, models with adult human dimensions were determined and the product named Brad of the Simulaids brand was selected. The general design of the first version of the training vest was determined by using the body measurements of this mannequin. Pattern files were created digitally in the Adobe Illustrator program using dimensions. The fabrics used in production were cut by printing on paper. The patterns on the vest were created by applying digital printing on the fabric. Pattern designs were created using the Adobe Illustrator program.

While determining the sensors in the vest, attention was paid to ensuring they were compatible with wearable technology. Paper-thin flat force sensors are preferred among the various force sensors on the market. After the researcher placed sensors and cables between two layers of fabric, an expert tailor sewed the fabrics together. Professional support was received for the sewing of the vest.

After determining the content of the mobile and desktop applications, mockups were created using the Adobe XD program. The design file of the first version applications was shared with the software developer through the Zeplin application. The coding processes of the applications were made using React Native.

The electronic card design, which provides data from the sensors and transfers the received data to the cloud system, was made together with the hardware developer. The researcher determined the dimensions of the electronic card and the features it should contain. The production of the card design created by the hardware engineer was done abroad. The researcher brought together all these components, revealing the first version.

### 4.2.1 Training Vest - V1

According to the information in the literature, there are ten chest physiotherapy zones in the lungs. These zones have been decisive in determining the general training vest design. In the design, graphic design elements were used on the vest to highlight the areas where chest physiotherapy will be applied. In this way, it is aimed that students' learning process is supported with visual guidance that appeals to the sense of sight. The visual design used in the first version is shown in Figure 4.4.


Figure 4.4. Pattern design for visual guidance of Physiocircle V1

In addition, flexible silicone parts in the form of domes were used within the physiotherapy zones. Conversation with the expert trainer inspired adding a dome-shaped design detail to the training vest design. According to expert opinion, one of the chest physiotherapy methods that students have the most difficulty learning is ‘clapping’. During this method, the hands should be kept in a cup-shaped form. It provides a more comfortable and practical physiotherapy session for the patient and physiotherapist with the air trapped in the palm. The form in which the physiotherapist's hand should be during the clapping application is shown in Figure 4.5.

Figure 4.5. Cup-shaped hand form

So, the flexible silicone parts stimulate the cup-shaped form used in the vest. These silicone parts provide the hands of the students to stay in the right way throughout the application. The silicone design detail used in the vest that provides this feature is shown in Figure 4.6.

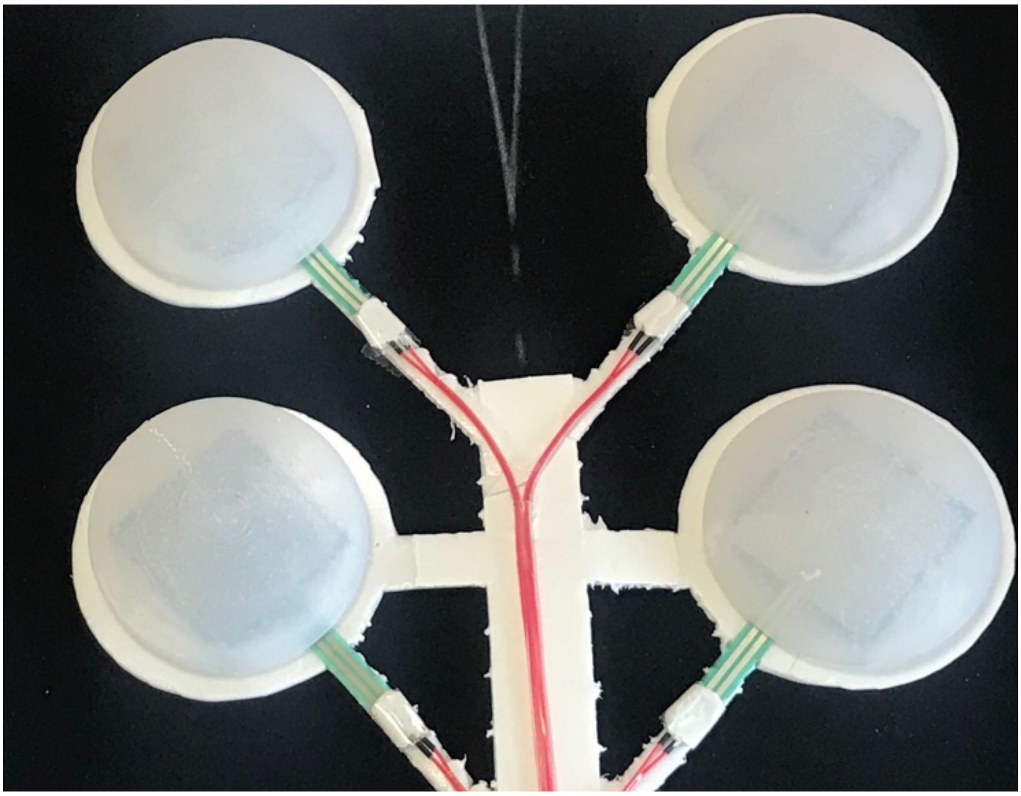

Figure 4.6. Flexible silicons with a Cup-Shaped form

The measurements of the training vest are designed to be compatible with the adult CPR training manikin of the Simulaids brand. The vest is provided with a simulation manikin so that students can practice manual chest physiotherapy without needing an assistant (instructor or student). The mannequin used in the focus group studies together with the vest is shown in Figure 4.7.

Figure 4.7. Simulaids® Brad Adult CPR Manikin
(https://simulaids.co.uk/product/simulaids-brad-adult-cpr-manikin-with-carry-bag/)

Preferring reason for this model is to provide adult human size and real human body feeling for students during the chest physiotherapy practice. Because students have limited access to real patients during undergraduate education, they graduate from university without experience. Training vest with adult manikin provides a simulation environment for students to gain experience about manual chest physiotherapy.

The Physiocircle training system is not only a concept training product that includes design suggestions. It is also fully functional with technological features. So, the technologies used in the training vest were also determined in the thesis process. Using fully functional prototypes during the focus group studies allows for effectively observing user experience and interaction.

As a result of the meeting with the expert, it was determined that the instructors wanted to follow the force, frequency, location, and duration data applied by the students in the chest physiotherapy sessions. So, flat force sensors, which are suitable for wearable technology and will enable the measurement of the data mentioned above, are used in the vest Figure 4.8.

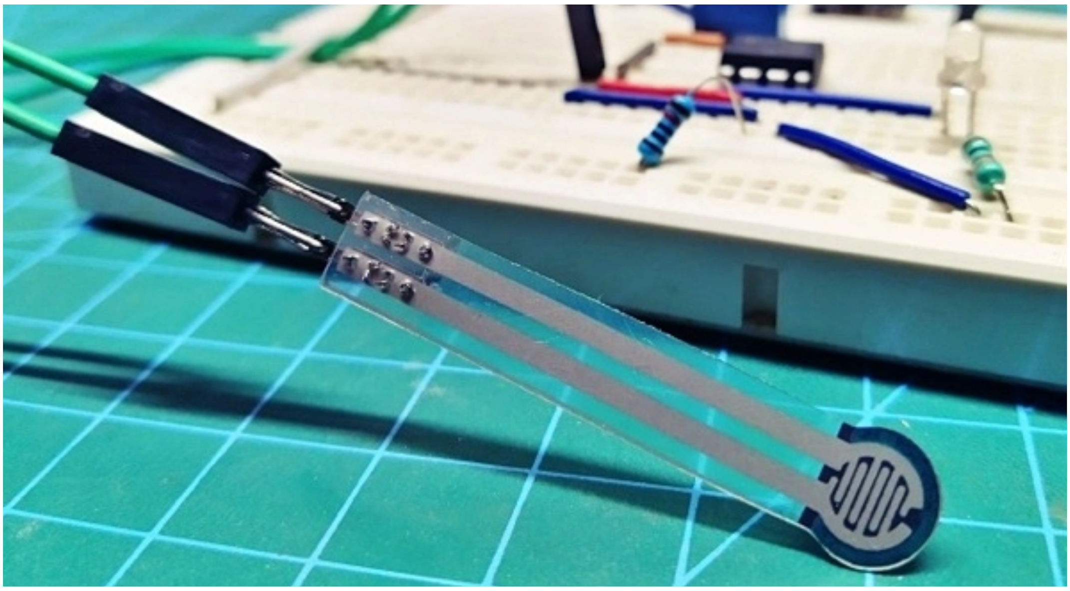

Figure 4.8. Flat Force Sensor Setup

Sensor technology has also been decisive in determining the contents and screen designs of integrated mobile applications to be designed.

### 4.2.2 Mobile Application – V1

It was decided after the expert interview to add a mobile application works on tablet within the Physiocircle education system. During the meeting, the expert mentioned that manual chest physiotherapy was applied individually depending on the patient's condition. For this reason, during lectures, students are asked to create a chest physiotherapy program by giving information about people with different respiratory diseases. The lack of a chance to learn about these diseases practically in the current education system constitutes a deficiency in education. Therefore, an integrated mobile application has been designed to enable students to practice using the training vest and manikin. While determining the application's content, attention was paid to keeping it simple and understandable for students. It has been decided to include a ‘case pool’ menu in the mobile application so that students can practice using cases created by instructors.

One of the most important points in chest physiotherapy is to tap at the right intensity. Visual guidance has been added by using color codes to instantly monitor the impact intensity of the students over the mobile application. As shown in the Figure 4.9, the yellow zone represents low-intensity taps, the green zone represents appropriate taps, and the red zone represents taps harmful to the patient's health.


Figure 4.9. The color code chart represents the tap's intensity

The 'Case pool' menu is another feature shaped with information from an expert meeting. The case pool offers possible patient cases that students will encounter in their professional life, such as asthma, COPD, cystic fibrosis, etc. Figure 4.10 shows the case pool menu in the application interface.

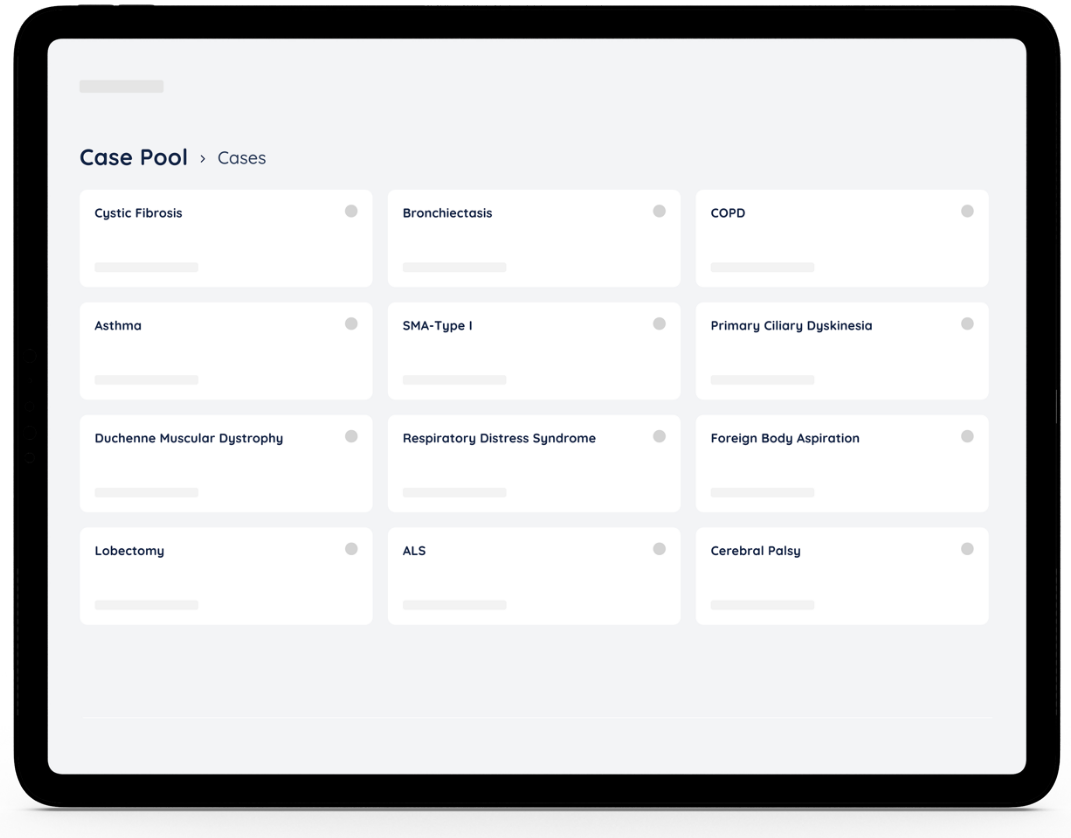


Figure 4.10. Case Pool Menu

The Case menu includes detail, visual content, and physiotherapy program submenus to explain the patient's health status. In addition, instructors could add video content to explain case-specific additional details. Thus, students can access theoretical information without needing physical contact with the instructor. Finally, the instructor can add the correct chest physiotherapy program to the mobile application, which should be applied to the patient. Hence students can practice by seeing the details of chest physiotherapy that should be applied to the patient. At this point, the data received from the sensors are transferred wirelessly to the mobile application. Figure 4.11 shows the program list created with data analyzed using artificial intelligence after applying chest physiotherapy.

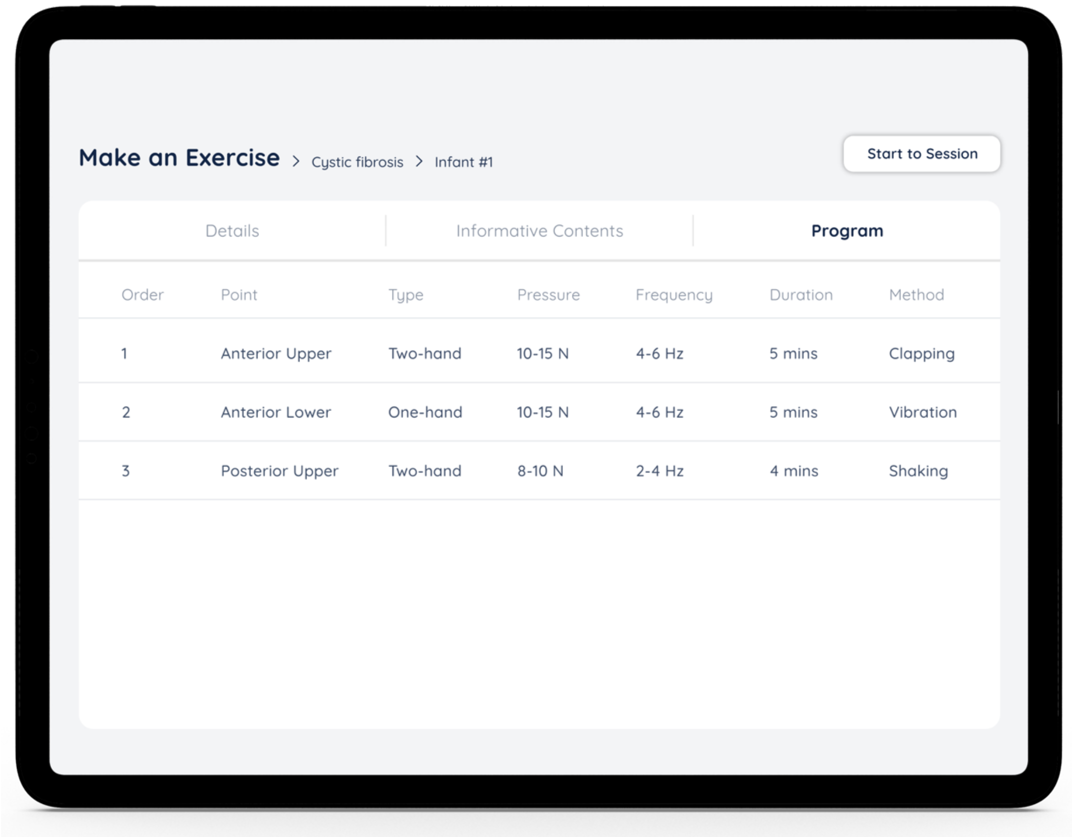


Figure 4.11. Chest Physiotherapy program details

### 4.2.3 Desktop Application – V1

One of the most critical problems identified in the expert interview and the literature research is the difficulty of student follow-up due to the increasing number of students. A desktop application has been added to the Physiocircle training system to find a solution to this problem. Thanks to the desktop application, instructors can keep track of students.

The contents of the desktop application are as follows;

- University account,

- List of students taking courses,

- Case Pool menu to create making physiotherapy practice content.

In addition, each instructor can add their students to the application. Thus, all students are registered in the application with their name, surname, and student number. Figure 4.12 shows the student list menu in the desktop application.

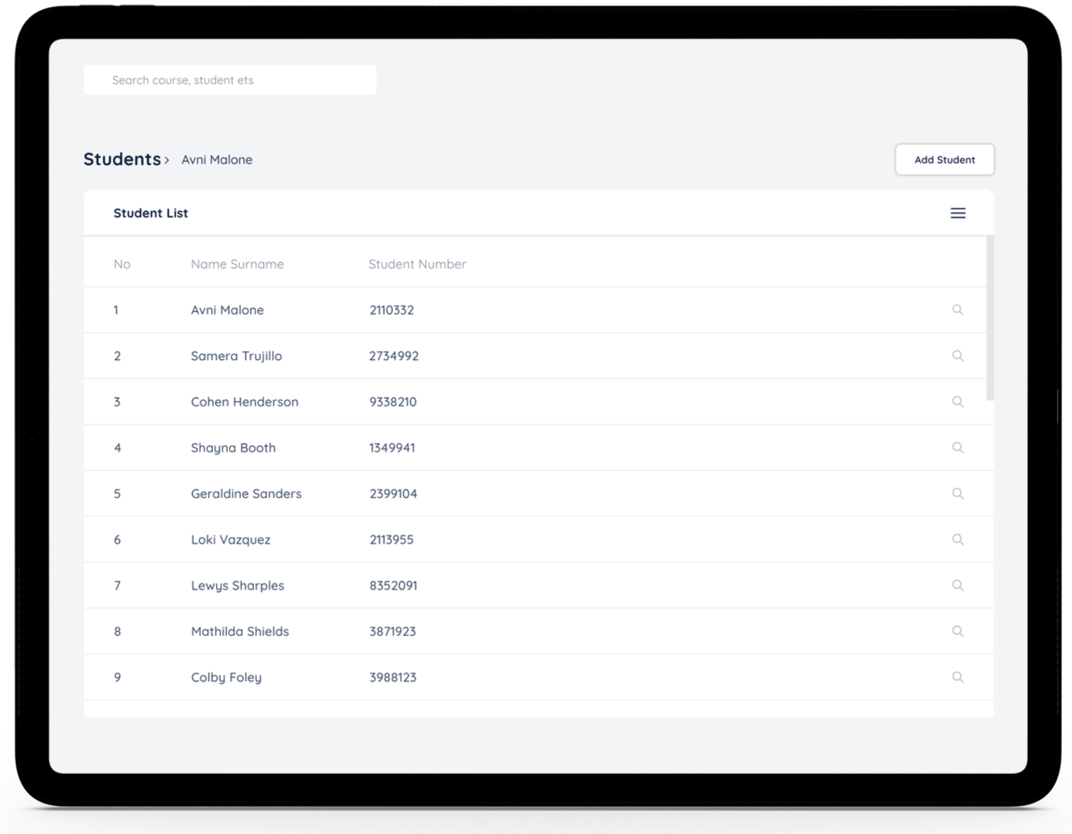


Figure 4.12. Student List

Lastly, instructors can add a patient case to the 'Case Pool' menu using the desktop application. Hence, instructors can create educational content for students in the digital environment.

## 4.3 Outcomes of the First Phase of the Field Study

After the first version of the Physiocircle training system was designed, a focus group study was conducted to learn experts' and students' comments, opinions, and suggestions. The participants in this group study were selected from among the instructors, assistants, and students working in the same physical therapy and rehabilitation faculty. During the focus group study, first of all, the participants were informed about the features of the training vest. Then, the usage of mobile and desktop applications were explained. Finally, the participants were asked to use the components of the education system. In the meantime, the users' interactions with the product were observed without intervention. Afterward, the participants verbally express their comments and suggestions. Figure 4.13 shows the outputs obtained as a result of the first focus group study.

Training Vest V1

| Design Features | Focus Group Study I - Findings | Focus Group Study I - Insights | V2 Design Decisions |
|---|---|---|---|
| Location of the physiotherapy zones | corrections should be made in the places of the points | determine correct position of points with the participants | The position of the points will be revised |
| Visual guidance pattern design | visual orientation pattern is distracting | an obvious and distinctive visual pattern | The visual design pattern will be changed |
| Does not contain design features | Unstable manikin during physiotherapy session | The mannequin must be kept stable | Positioning pillow will be add to system |

Mobile Application V1

| Design Features | Focus Group Study I - Findings | Focus Group Study I - Insights | V2 Design Decisions |
|---|---|---|---|
| Manually entering physiotherapy program details | time-consuming and impractical method | save program details in a practical and easy way | Artificial intelligence technology will be added |
| The color codes displayed for guidance | difficult for students to focus during physiotherapy practice | simple and understandable interface design | The color code system will be removed |
| Does not contain design features | physiotherapists adjust their taps according to the patient's breathing | thoracic expansion breathing | thoracic expansion breathing graph will add to interface |

Desktop Application V1

| Design Features | Focus Group Study I - Findings | Focus Group Study I - Insights | V2 Design Decisions |
|---|---|---|---|
| Case creation menu includes "detail" and " program" tabs | physiotherapists need more information about the patient's | Specialized tabs to add more information and visual elements (X-rays) | Provides more field for patient's status and conditions |
| Does not contain design features | couldn't follow the students' physiotherapy practice results | Instructors want to follow & evaluate students' records | Students' physiotherapy results will add |
| One account for all instructors | Instructors asked for individual access to desktop application | 'Personal space' | Each instructor will have an individual account |

Figure 4.13. Outcomes of the Focus Group Study I

### 4.3.1 Feedback and Suggestions for Vest - V1

The initial feedback on the training vest was related to the location of the physiotherapy zones. It was stated that corrections should be made in the places of the points located on the vest. Figure 4.14 shows the locations of the zones in the first version training vest.

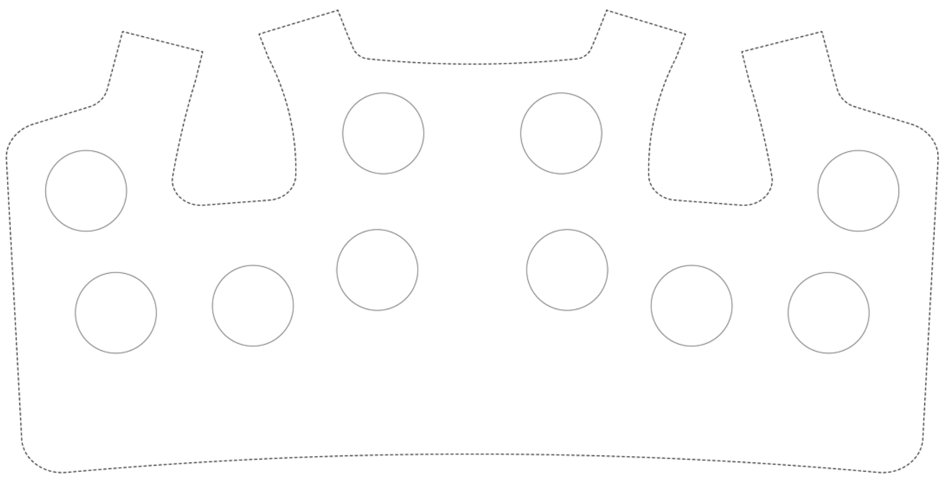

Figure 4.14. Physiotherapy zones of V1 vest

In addition, it was suggested that the visual directions used on the vest should be more obvious and distinctive. It was stated that the current design could not adequately give the desired steering feeling. The pattern used in the first version training vest is shown in Figure 4.15.


Figure 4.15. Visual guidance pattern design

Finally, it was observed that the instructors practiced by placing the manikin in different positions during chest physiotherapy. Both in the observation made during use and in the comments of the participants, the inability of the training mannequin to stand still in different positions negatively affected the user experience.

### 4.3.2 Feedback and Suggestions for Mobile Application – V1

The process of saving the chest physiotherapy program to the application is possible by manually entering the intensity, frequency, and duration information of all the taps to be applied throughout the program into the system one by one by the instructor. This situation was described as a time-consuming and impractical method by the instructors. In addition, firstly the instructors needed to learn these values precisely because they had never worked with a device that measured the data (intensity, frequency) of the chest physiotherapy they applied before. For this reason, there have been requests to offer a different kind of interaction for adding a physiotherapy program to the system. The screen for adding the physiotherapy program to the application is shown in Figure 4.16.

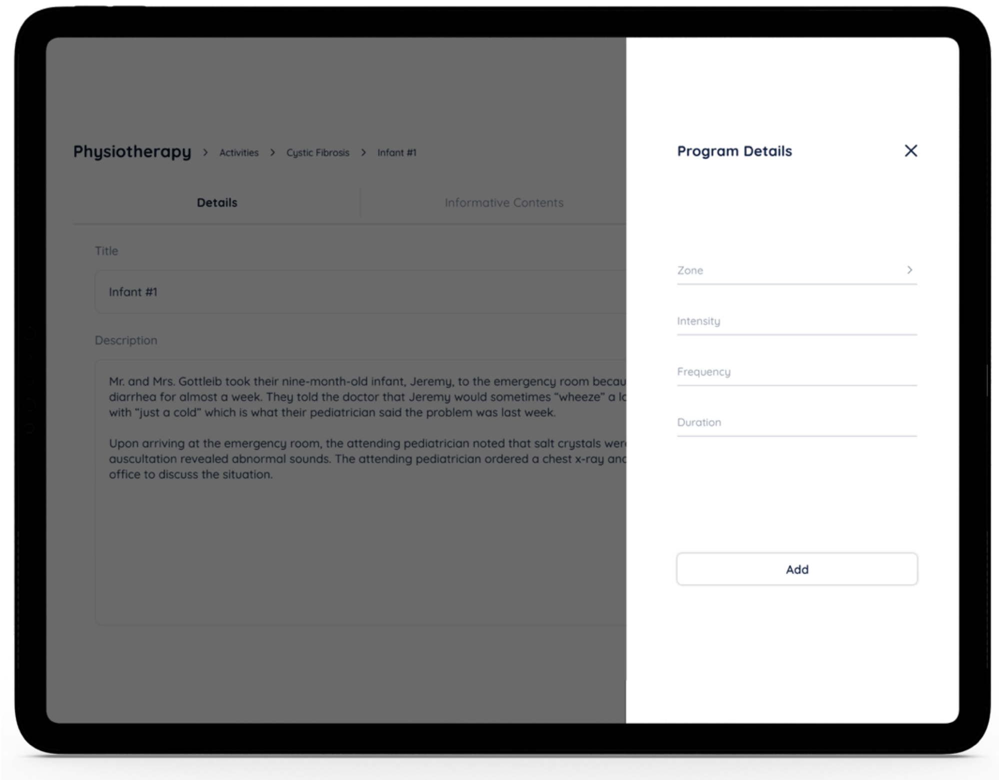


Figure 4.16. Adding chest physiotherapy program details manually

During the physiotherapy application, the students adjust their tap intensities instantly according to the color codes displayed on the screen. This situation makes it difficult for students to focus during physiotherapy practice. In addition, the instructor's feedback stated that the patients breathe in a way called “thoracic expansion breathing” during chest physiotherapy. By teaching this breathing style to the patient, mucus excretion is maximized during chest physiotherapy. In addition, physiotherapists adjust the intensity, frequency, and duration of the taps according to the patient's breathing. For this reason, a thoracic expansion breathing graph was requested to be added to the mobile application. Figure 4.17 shows the graph of thoracic expansion.

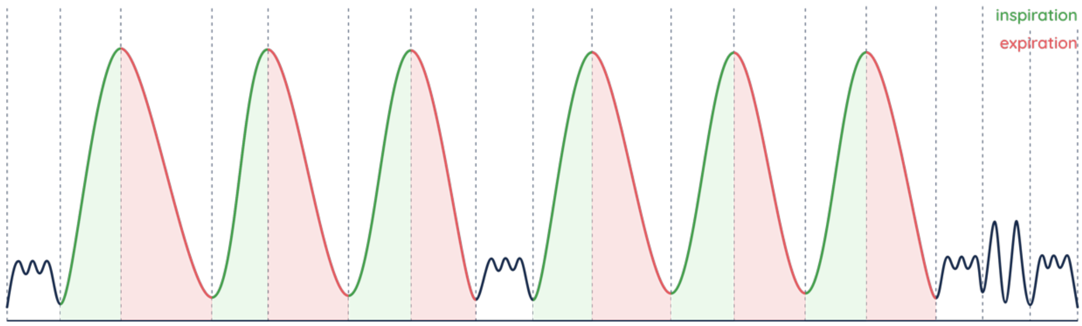


Figure 4.17. Thoracic expansion breathing graph

It has been observed that adjusting the tap intensities of the students using color codes causes the users to follow the screen constantly and reduces the effectiveness of the physiotherapy application. Contrary to popular belief, it has been understood that giving feedback after the student has implemented the entire program will provide a better user experience rather than continuously monitoring each tap's accuracy.

### 4.3.3 Feedback and Suggestions for Desktop Application – V1

In the case creation menu, more information about the patient's health status would be needed to understand the case. It was stated that data such as disease history, previous treatments, vital signs, and chest X-rays should be analyzed to create a chest physiotherapy program. While creating the case, the instructor was requested to add this information to the system. Figure 4.18 shows the case example given to the students in english.

**CASE 1**

**Lobectomy**

The 15-year-old patient applied with a history of recurrent respiratory tract infections. As a result of the examinations, the patient was diagnosed with congenital cystic adenoid malformation localized in the lower lobe of the right lung. He had a right lower lobectomy operation 2 days ago. On the 2nd postoperative day, consultation from the cardiopulmonary rehabilitation unit was requested to evaluate it in terms of respiratory physiotherapy.

**Surgical Operation:** Right lower lobectomy

**Inspection:** Assisted respiratory muscle activity is present. No cyanosis, peripheral edema, and clubbing.

**Auscultation:** Widespread coarse crackles in the right lung fields

**Chest X-ray:** Atelectasis areas in the right lower lobe

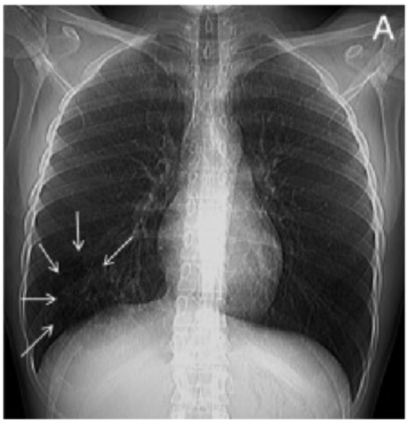


Figure 4.18. Case example format used in ‘'traditional'’ education

The data of each chest physiotherapy applied by the students were requested to be presented as a report by instructors. Comparatively, presenting this report to the instructors would be beneficial in evaluation.

It was stated that having separate accounts for instructors instead of a single account to be used by all instructors will increase the user experience. The common account used by all instructors is shown in Figure 4.19.

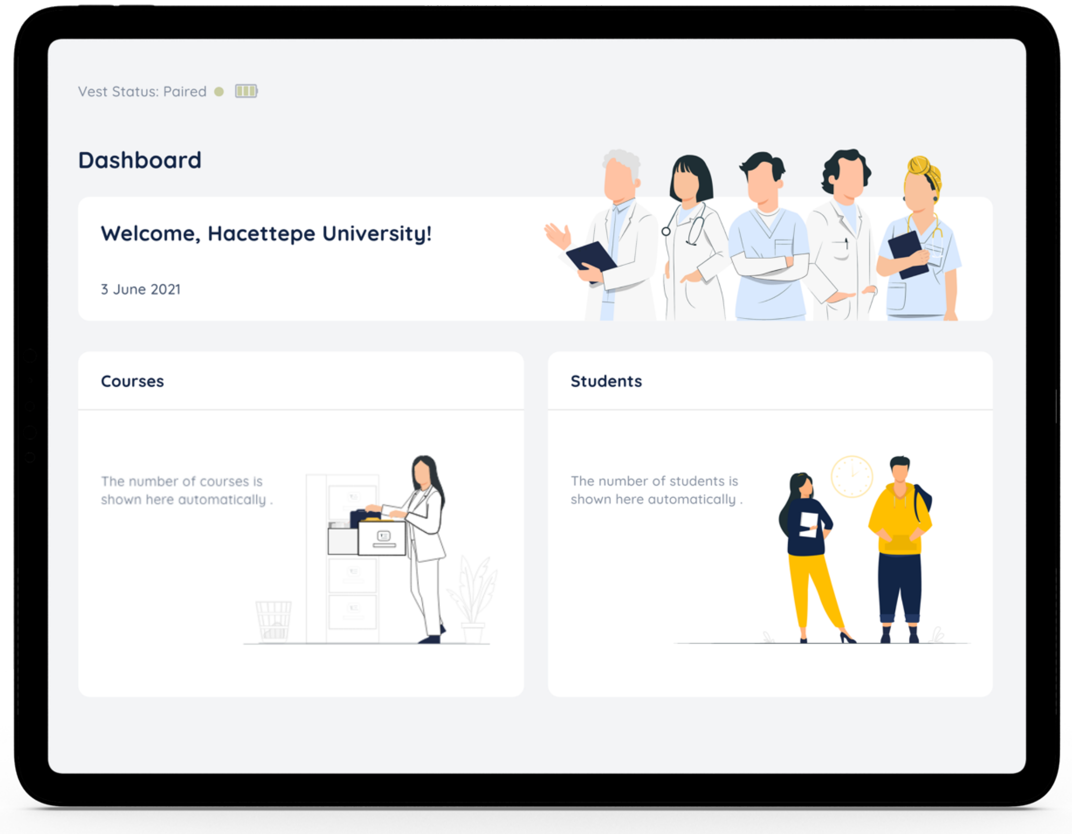


Figure 4.19. Welcome screen when logging in from the institution account

# CHAPTER 5

# RESEARCH THROUGH DESIGN – PART 2

The outcomes of the first focus group session were revisited to determine points that could be considered throughout the revision of Physiocircle V1.

Accordingly, this chapter begins with an explanation of Physiocircle V2 design revisions shaped with participants' feedback and suggestions. Afterward, a focus group study was conducted using the second version of Physiocircle. As in the previous section, the comments and suggestions on each education system component were mentioned. These comments will then be used to discuss potential features and revision suggestions that could be added to further versions of the Physiocircle training system.

## 5.1 Design and Production of the Physiocircle – V2

The previous chapter explains the considerations for designing the second version of Physiocircle separately for each component. Considering these outcomes, arrangements and revisions were made in the physiotherapy vest, mobile application, and desktop application. All revisions are explained in detail under the relevant heading.

The physical and digital components of the second version were produced by following similar steps as in the first version of Physiocircle. While applying for expert support for the training vest, engineers worked together to develop the mobile application and electronic card.

### 5.1.1 Training Vest – V2

In the first focus group study, feedback was given on the location of the physiotherapy zones. The participants confirmed the correct positions of these points during the focus group study by showing them on the vest. The vest design was revised according to these new positions. Figure 5.1 shows the locations of the physiotherapy points in the new version.

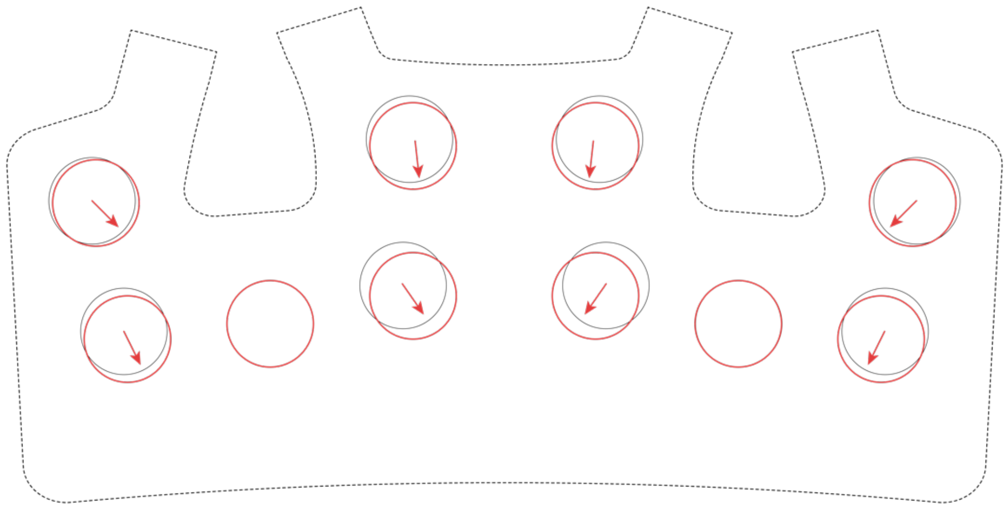

Figure 5.1. Point correction for physiotherapy zones V2 vest

Another significant change was made to the visual pattern design used on the vest. The pattern design represents the physiotherapy areas that were made simpler and more attractive. The new pattern design is shown in Figure 5.2.

Figure 5.2. Training Vest V2 – Visual Guidance Pattern

Finally, the problem of the training manikin's inability to stand still in different positions during physiotherapy practice was discussed. As a solution proposal to this problem, it was decided to add a positioning pillow to the education system. Thus, the manikin stands stable in all positions needed during chest physiotherapy. The positioning pillow included in the education system is shown in Figure 5.3.

Figure 5.3. Positioning pillow

### 5.1.2 Mobile Application – V2

Instructors have given feedback about adding a chest physiotherapy program to the case content process to make it easier and more practical. In the second version, it has been understood that more than design changes are needed to improve the user experience. Thus, available technologies that can detect the physiotherapy program autonomously have been searched. Research outcomes showed that analyzing data collected from the force sensors with Artificial Intelligence technology can be used for autonomously listing physiotherapy programs in mobile applications.

Thus, artificial intelligence technology has been added to mobile application. This has led to changes in screen designs and the usage scenario. Adding illustrations to the screen designs makes it easier for the users to use the artificial intelligence system. Figure 5.4 shows the visual directions added to the application.

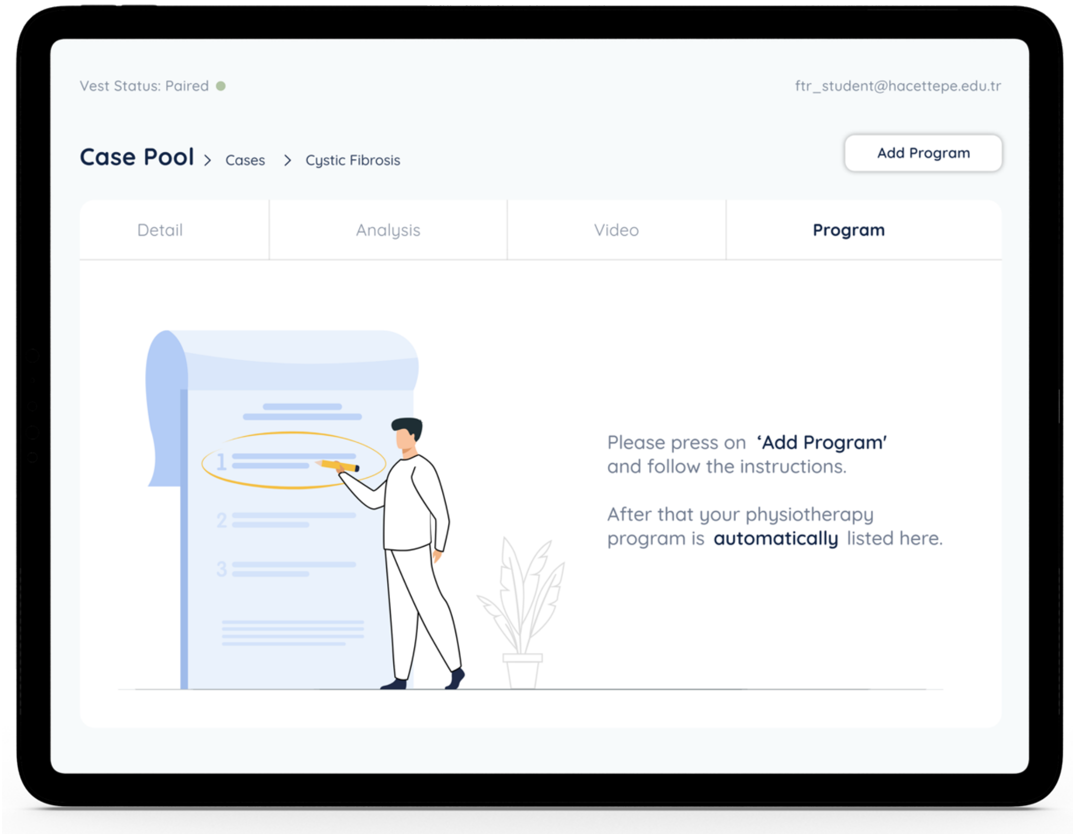


Figure 5.4. Visual Guidance to explain AI System

In addition, thanks to the new design and technology, the trainer can complete the physiotherapy program creation process by using the training vest and mobile application. Figure 5.5 shows the expert testing the artificial intelligence system in September 2022.

Figure 5.5. Chest Physiotherapy program preparation

Other suggestions regarding the mobile application were related to the interface students interact with while practicing physiotherapy. In the first version, the intensity of each student's tap was instantly displayed on the screen with color codes. It has been noticed that this situation prevents users from focusing on physiotherapy and does not positively affect the learning process. In the second version, color codes are entirely removed from the application. Instead, students were allowed to see the physiotherapy values applied by their instructors in comparison with their values whenever they wanted. The practice screen design in the new version is shown in Figure 5.6.


Figure 5.6. The ‘Compare with instructor’ feature that students can compare their values with the instructor

Additionally, users mentioned that the first version needs a guiding design element to help students adjust their tap intensity and speed. For this reason, integrating the thoracic expansion graph into the practicing interface has been requested. A thoracic expansion graph has been added to the interface students can follow while practicing physiotherapy. Thus, students can arrange their intensity, speed, and duration values according to the patient's breathing.

### 5.1.3 Desktop Application – V2

The sub-menus used in the adding case interaction was not found sufficient by the trainers. For this reason, the case samples given to the students in the current chest physiotherapy lectures were requested and analyzed at the end of the focus group study. According to this examination, new sub-menus have been added to the mobile application to ensure that the case creation part is compatible with the existing system. By examining these case examples, the common framework of the case creation system was determined and added to the mobile application. Accordingly, in a typical case example, the patient's personal information (gender, age, weight) is first presented to the students. In addition, information such as the patient's disease history, treatments, and chest x-rays are provided. After the case is explained, the analysis part is also given, explaining the treatment program that should be applied to the patient. The case creation section has been revised to have four subheadings. These are in the form of 'detail,' 'analysis,' 'video,' and 'program'. The contents of these submenus are shown in the figures. The designs of the new screens added are shown in Figures 5.7 and 5.8.

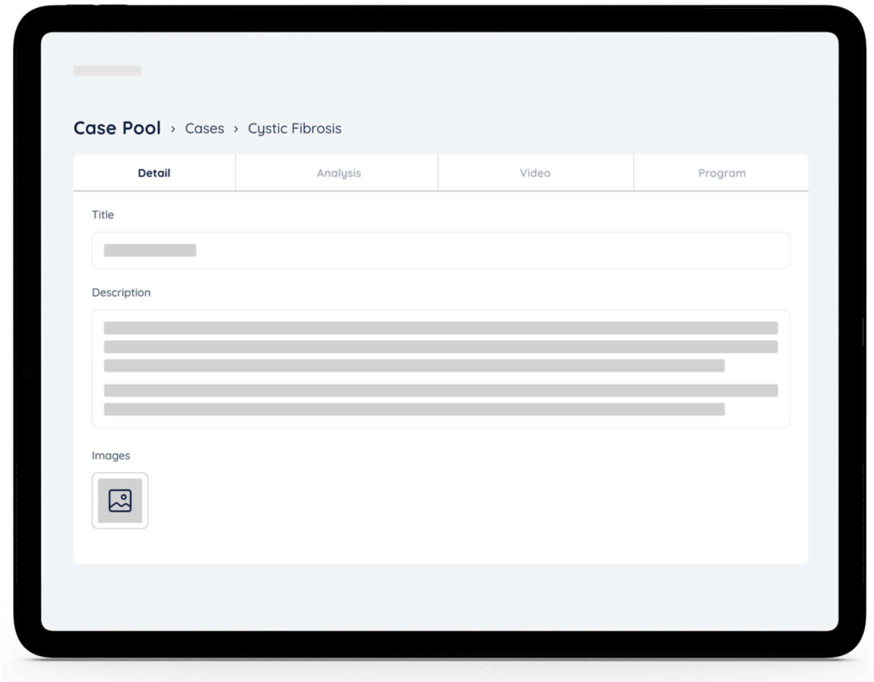


Figure 5.7. ‘Create Case’ interface with new headings

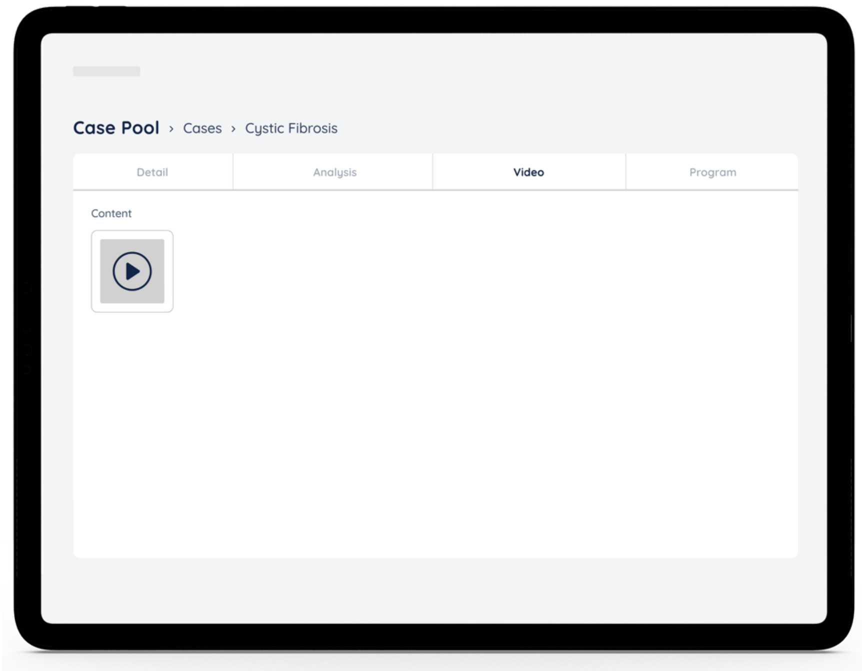


Figure 5.8. Case Pool - Video

Another of the comments made in the focus group study on the first version desktop application was about the inability to follow the physiotherapy results applied by the students. In line with the demand from the instructors, it was decided to present a report screen using data received from sensors. The sensors in the vest can detect the intensity, frequency, location, and duration data of each student's taps. The physiotherapy summary report can be accessed by entering the profile page of the relevant student. In this way, the physiotherapy summary report of the desired student can be examined in a digital environment via the desktop application. The student list interface that instructors can access via the desktop application is shown in Figure 5.9.

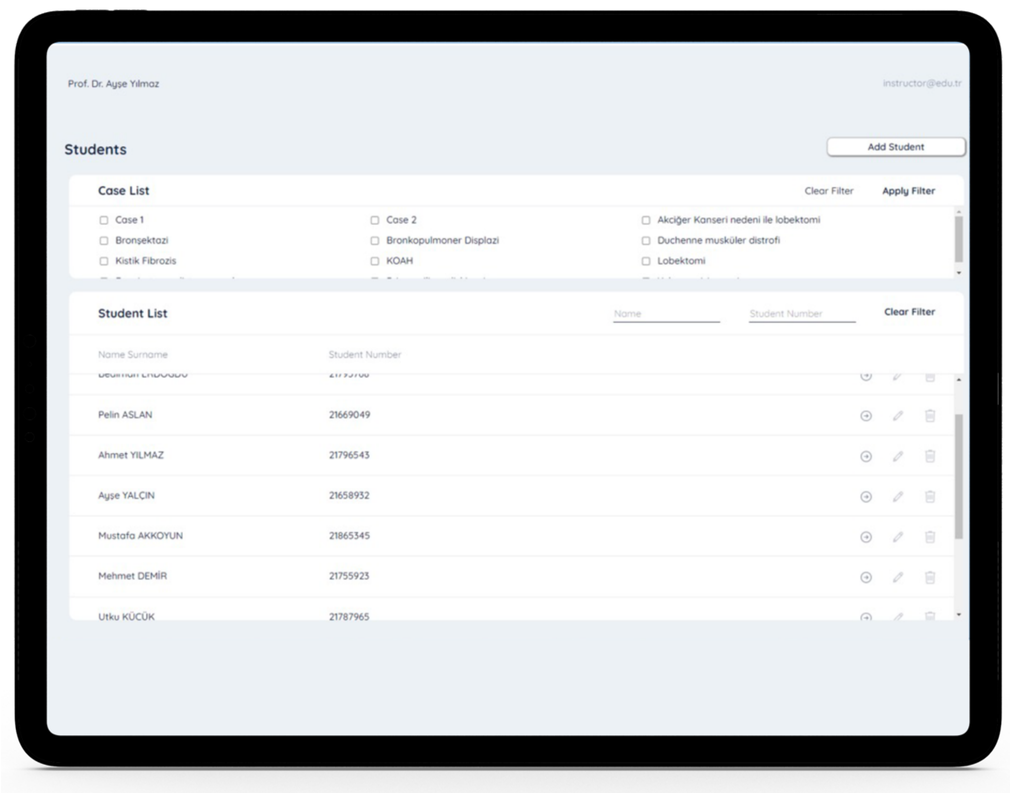


Figure 5.9. Student List

In addition, the report screen design showing the data of the physiotherapy practices completed by the students is shown in Figure 5.10.


Figure 5.10. Student summary report

The last feedback regarding the desktop application is related to the login process. In the first version, a single account belonging to the educational institution was used for logging in to the desktop application. In the comments made in the focus group study, it was determined that each instructor wanted to log in to the application with their account. The main reasons for this are the instructors' desire to monitor their student data separately and to ensure personal privacy. Therefore, each educator can create an individual account in the second desktop application version. Thus, educators were prevented from accessing each other's accounts and seeing the personal information they added to the system. The process of creating a personal account and logging into the application is explained in the figures. The interface design that provides access to the personal accounts of the trainers is shown in Figure 5.11.

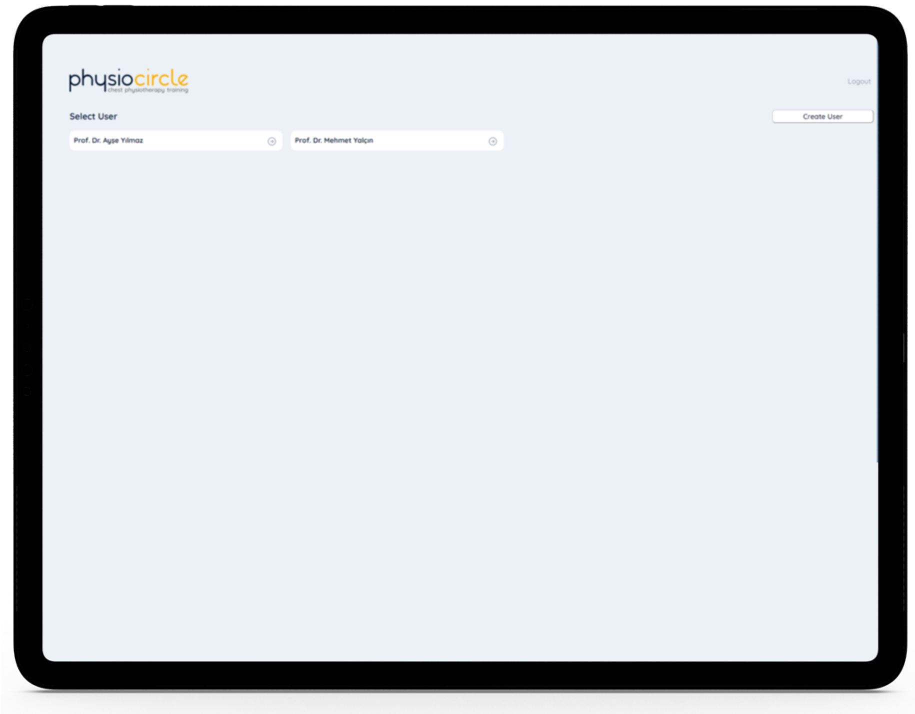


Figure 5.11. ‘Select the User’ interface

## 5.2 Outcomes of the Second Phase of the Field Study

After the revisions of the second version Physiocircle education system was completed, a focus group study was conducted again. Care was taken to ensure that the participants were the ones who participated in the first focus group study. The people who participated in the first study were re-preferred because they could better observe the changes between the first and second versions. In addition, the sense of belonging to the product development process will be higher than those who will participate in the study for the first time. Figure 5.12 shows the outputs of the second focus group study.

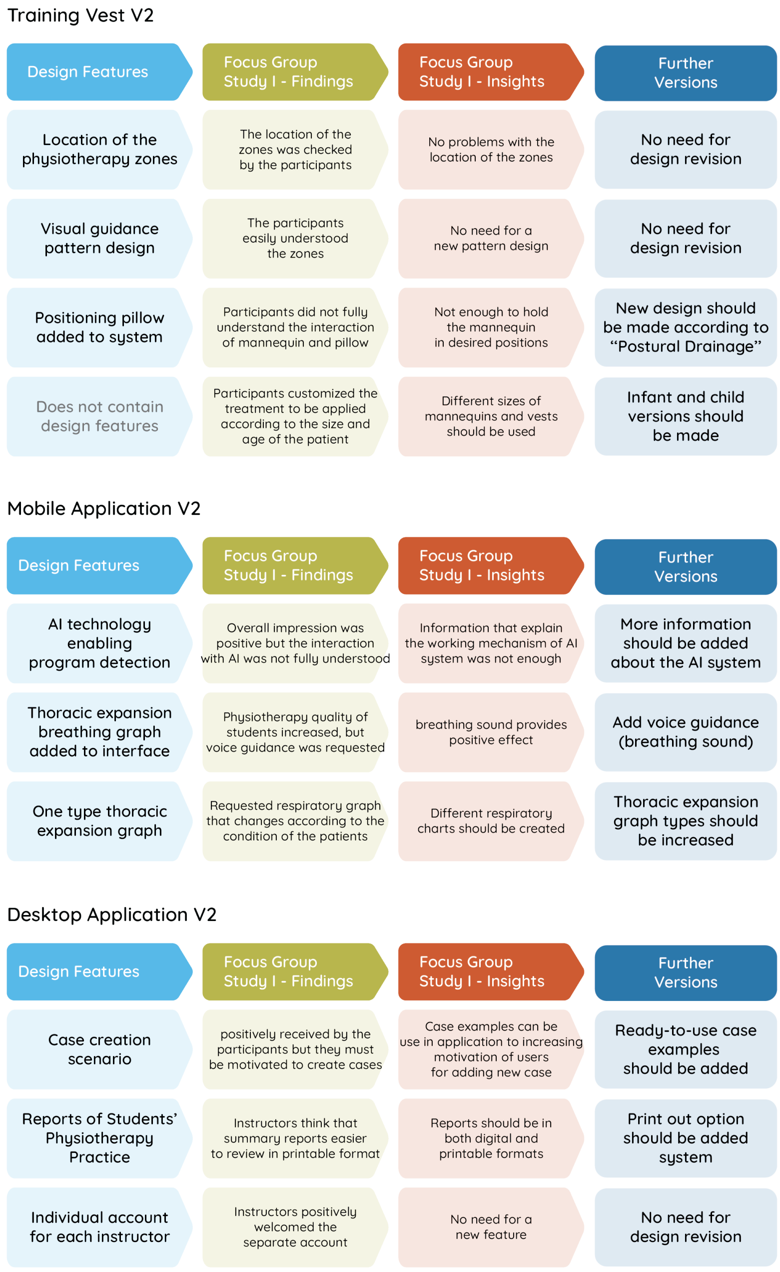


Figure 5.12. Outcomes of the Focus Group Study II

As in the first study, the changes and additions made in all system components were presented to the participants. Afterward, the participants were asked to use the education system. Throughout this process, users were observed without interference. During the focus group study, participants' suggestions about the components of the second version were received. These comments and suggestions obtained were analyzed regarding the training vest, mobile application, and desktop application, and the outputs were explained in the next section.

### 5.2.1 Feedback and Suggestions for Vest – V2

The instructors were satisfied with the graphic pattern change and the positioning of the physiotherapy points in the training vest.

It has been stated that the positioning pillow added to the system has a positive effect on the user experience during the physiotherapy application. While applying manual chest physiotherapy, positioning is essential to contribute to removing mucus from the body with the effect of gravity by placing the patient in different positions. These positions, which are defined as ‘postural drainage,’ are shown in the figure. It has been observed that positioning a pillow is not an exact solution due to the form of the training manikin and the having a general design suitable for a limited number of positions. The participants emphasized that the positioning problem could be resolved in future versions. The positions used during postural drainage are shown in Figure 5.13.

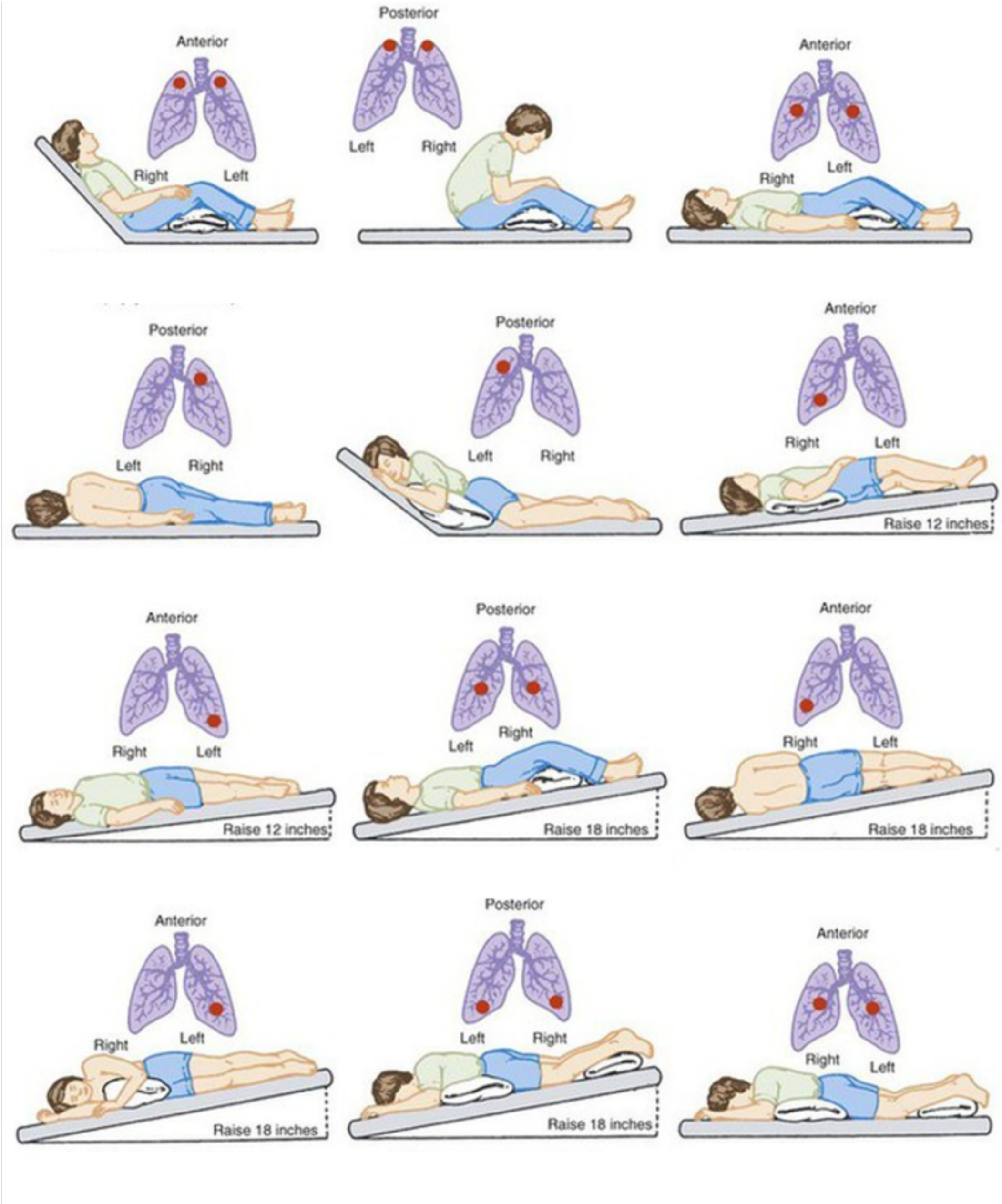


Figure 5.13. Patient positions for postural drainage. (Modified from Potter PA, Perry AG: Fundamentals of nursing: concepts, process and practice, ed 4, St Louis, 1997, Mosby. In Wilkins RL. Egan's Fundamentals of Respiratory Care, ed 9. St. Louis, 2009, Mosby).

Regardless of the revisions, participants stated that designing training vests suitable for different sizes of mannequins (infant and child) would positively affect the training process. Because in chest physiotherapy training, the application method is arranged according to the patient's age. So, it has been mentioned that using appropriate manikin during chest physiotherapy is necessary for proper and practical education. The mannequin family that will meet this need is shown in Figure 5.13.

Figure 5.14. Training Manikin Family Set (https://anatomywarehouse.com/sani-cpr-manikin-family-pack-a-103429)

### 5.2.2 Feedback and Suggestions for Mobile Application – V2

The experience of creating a physiotherapy program using the artificial intelligence system, one of the main changes made in the second version, received positive feedback from the participants. Participants mentioned that the application of physiotherapy to the manikin is as if the users are accustomed to treating a patient. Thus, automatically listing the program details in the application improves the user experience. However, it has also been observed that people working in the health field cannot use the new feature effectively enough because they have less aptitude for technology and need more information about the functioning of the artificial intelligence system.

It has been determined that the thoracic expansion graph added to the interface seen while practicing chest physiotherapy positively affects the physiotherapy performance of the participants. Students can focus more on the patient without constantly following the interface. Users have arranged their tap intensities, speeds, and the method they apply in a way that considers this graph. However, it was suggested by the participants that more than the respiratory expansion chart would be required besides adding respiratory sound (auditory guidance) to the mobile application to match the graph.

Another comment about the thoracic expansion chart was about adding different versions of the breathing pattern used in the application. It was mentioned that the 80-second respiratory chart used in the second version is only suitable for some patient types. Instructors emphasized that different patients can have respiratory charts in different patterns, so increasing the diversity would benefit students to gain experience.

Finally, it was stated that instead of displaying each tap value of the students on the interface, showing all the data of the physiotherapy session is a more accurate method for the students to focus on the whole treatment. In addition, it has been observed that the student's ability to examine the physiotherapy data of their instructors during the application will positively affect the education process.

### 5.2.3 Feedback and Suggestions for Desktop Application – V3

The case creation system in the second version, created by examining the existing education system, was positively received by the users. Moving the familiar system to the digital environment made the usage scenario more accessible and understandable for the instructors.

The instructors in the first focus group study specially requested that the reporting feature be added to the second version. Keeping track of students was one of the most critical issues that instructors were concerned about due to the increasing number of students. So, instructors found it helpful to present the data on the chest physiotherapy practices applied by the students in the form of a summary report. It is particularly appreciated that the information presented on the report screens is simple. It was emphasized that in addition to the current reporting system design, it would be beneficial to introduce the ability to print out the reports prepared in the digital environment.

Finally, it was appreciated by the trainers that a separate account was created for each trainer and that each user only had access to their account. This way, it was emphasized that problems such as data breaches and loss could be prevented.

### 5.3 Suggestions for Further Design Iterations

Focus group studies were conducted using Physiocircle V1-V2 training systems in the research through design (RtD) carried out within the scope of this thesis. The primary purpose of using concept training products during these studies is to increase the participants' contribution to product development processes carried out with people from different disciplines and to ensure the commitment of people unfamiliar with the concept of design. Two focus group studies and design revisions were made in the field study part of the thesis process. Since product development is an ongoing process, it is open to innovation depending on user requests. Moreover, because of the thesis's limited time, a third product revision has not been made. Instead, the data obtained in the second focus group study are analyzed, and possible design improvements that can be made in the following versions are explained in this section.

This part presents further suggestions for the later versions of Physiocircle training system, organized under these headings with a structure similar to the research through design I chapter: *training vest, mobile application, and desktop application.*

#### 5.3.1 Further Versions of Smart Vest

During the thesis study, the training vest was designed to be compatible with the adult mannequin. Redesigning the existing training vest according to infant and child mannequins using the knowledge gained will improve the user experience. Thus, the quality of education will be increased by allowing students to practice physiotherapy with mannequins from different age groups.

The positioning pillow design process needs independent research and product development when considering different positioning during postural drainage. The instability of training manikin showed that a different solution proposal was needed in this regard. So, the design of the positioning pillow supplied with the mannequin needs to be rethought.

### 5.3.2 Further Versions of Mobile Application

Although the process of creating a physiotherapy program has been improved for users by integrating artificial intelligence technology into the system, it has been observed that this technology cannot be used effectively because it is up-to-date, and users need more knowledge about it. To improve the user experience in further versions, it will be helpful to add design details that will guide the users within the mobile application and explain the artificial intelligence technology clearly.

Adding the thoracic expansion graph to the mobile application helped the students practice physiotherapy without having trouble focusing. In future versions, adding auditory guidance (patient breathing sound) to the application may improve this experience. In addition, the trainer should create a respiratory chart suitable for different patient cases instead of a single thoracic expansion chart. This way, diversity can be provided by adding a wide variety of respiratory charts to the mobile application.

### 5.3.3 Further Versions of Desktop Application

Ready-to-use case examples can be added to increase the intelligibility of complex features, such as case creation. Thus, instructors can easily understand the system's functioning by examining these ready-made cases.

In the Physiocircle education system, digital applications have made the existing chest physiotherapy education modern and technological. However, in the comments from the instructors, it was understood that completing the whole process in a digital environment is not a desired feature. The most significant indicator is that they want to print out the student reports recorded digitally as hardcopy. For this reason, printing out documents such as patient cases and student summary reports can be added to future versions.

# CHAPTER 6

# CONCLUSION

This chapter discusses the conclusions obtained from the study. This chapter summarizes the steps carried out during the study, continues by revisiting of the research questions and limitations of the study. Finally, it continues with recommendations for future work.

## 6.1 Overview of the Study

This study aims to provide designers and design students a new perspective on the educational product development process in clinical practice.

The study started with a literature review on health education. The literature review continued with respiratory physiotherapy and manual chest physiotherapy. In addition, the concept of research through design has been included in the literature research. The literature review contributed to the conclusion of the research questions and provided in-depth information required to prepare for the expert interview. Along with the preliminary research, the existing literature revealed the methods used in health education and the necessity of an innovative educational product in respiratory physiotherapy. Therefore, the preliminary research continued with in-depth research supported by expert opinion.

Later, the researcher conducted a design process for a physiotherapy training product concept and Physiocircle V1-V2 used in focus group studies. During the focus group studies, the researcher met with four instructors, three assistants, and three students.

After each Physiocircle version was designed, field research was conducted with the same participants. During the field study, a presentation about the product was made to the participants by the researcher. Afterward, while participants used the training product, the researcher observed the user experience. Finally, the field studies were completed by taking the opinions and suggestions of the participants about the product version. The researcher conveyed the findings from the field research and personal experiences to give the designers a new perspective on the development process of clinical practice products.

## 6.2 Research Questions Revisited

The research was shaped with two main research questions and aimed to answer these respectively. These questions are:

i. What are the experiences of designers in the clinical practice product development processes carried out with physiotherapy students and instructors?
ii. What are the challenges that industrial designers may encounter during the incorporation of healthcare professionals into industrial design processes?
iii. What should be considered when designing clinical practice products?

The first research question deals with the experiences of designers in product development processes with people from the discipline of physiotherapy. The second question aims to present a new perspective on the product development process by conveying the challenges faced by the researcher in the collaborative working process. Studies on the first research question provided in-depth knowledge of the research area. The second research question presents an overall deduction from the study to assist designers and design students in the clinical practice product development process.

**i. What are the experiences of designers in the clinical practice product development processes carried out with physiotherapy students and instructors?**

The product design process in clinical practice requires designers to work with experts from different disciplines. During this thesis, the researcher completed the product development process with trainers, assistants, and student physiotherapists. The first of the experiences gained in this process is to carry out expert interview by making preliminary preparations. Knowing in depth the methods used in physiotherapy training ensures that the designer and the specialist can speak in a common language. Therefore, for productive meetings, designers need to acquire technical knowledge of the research field. In addition, preliminary preparations should be made to get efficiency from field studies with people far from understanding design. In this thesis process, prototypes of concept designs were produced and used in field studies as a preliminary preparation. This approach may be suitable for designers considering product development in this field.

**ii. What are the challenges that industrial designers may encounter during the incorporation of healthcare professionals into industrial design processes?**

The first of the difficulties encountered during the thesis process was being able to communicate with expert physiotherapists working in the research area. The keywords from the literature review helped create a list of experts operating in the relevant field to ensure the first interaction. Afterward, making an appointment request and meeting face-to-face is an effective method suggested by the researcher to reach experts.

The second challenge encountered throughout the process was creating a common language in field research with experts. Because of undergraduate-level design education, designers tend to collaborate with people from different disciplines. However, as a result of the interview, it was observed that the interaction of physiotherapists with people from different disciplines was low. Therefore, they needed to become more familiar with the collaborative work culture. Thus, it was necessary to inform the physiotherapists about the concept of design and the job description of the designers.

Another area that designers may need help with in developing products to be used in health education is that the definitions on the subject of research are detailed and challenging to understand. The education of different disciplines in health often covers each other's topics, as physiotherapy students learn lung anatomy as much as medical students. Therefore, in the expert interview and field studies, the designer should gather enough information from the literature to fully understand the feedback and suggestions. This way, designers can communicate more comfortably with experts during the interview.

Another challenge is to ensure that participants take an active role in the process during field research. The contribution of physiotherapists depends on the designer's preparation before the field research. Representing the design ideas on a physical prototype instead of explaining them verbally will increase the motivation of the participants to understand and contribute to the process. However, this creates a different challenge for designers. Prototyping design ideas is a time-consuming process. Moreover, depending on the product's technical details, getting help from experts from different disciplines (such as software specialists) is necessary. The design researcher has to plan this process and complete it within the thesis period.

### iii. What should be considered when designing clinical practice products?

Determining the content of the products to be used for clinical practice in health education is the first step in the design process. At this point, working in a defined area (manual chest physiotherapy) is vital for the designer to manage the process instead of trying to find solutions for a wide area (respiratory physiotherapy).

Another critical point is to determine what the content of clinical practice covers and how it is carried out in the current system. In this way, the designer can determine the features that users need. Because the information obtained as a result of research in the field of medical education can be comprehensive and difficult to manage. At this point, it is not possible for the designer to offer a solution that will meet all needs. For this reason, focusing on one area in the medical training and limiting the solution proposals will help the designer to manage the process.

Supporting clinical practice design with physical and digital products will help the designer respond to users' needs. Although digitalization in education has become increasingly important in recent years, it still has an important place in education for health professionals to gain experience through hands-on training. For this reason, supporting the design with a physical product instead of fully digitalized (AR, VR) solutions will increase the effectiveness of the solution offered.Thus, students can practice in the physical environment, while instructors can follow students' progress digitally.

Finally, providing directions and summary reports to users within the designed training system will improve the user experience. In this way, while the motivation of the users to use the product will increase, it will be ensured that the designed product can be used in future academic studies.

## 6.3 Limitations of the Study

The first known limitation was related to semi-structured interview with expert. Designers have the competence to come together with people from different disciplines and collaboration works. However, the complexity of the technical concepts used in medicine can prevent the meetings from being productive. To prevent this adverse situation, conducting deep medical literature research on the subject is necessary before conducting expert interviews. In this way, the participant can complete the interview without questioning the medical competence of the interviewer and without restricting himself/herself in the transfer of information. In addition, one expert interview was conducted within the scope of this study. Finding and interviewing experts related to the research topic was one of the limits in the thesis process. However, the expertise of the interviewee was sufficient for the research process.

Another known limitation was to research through design approach used throughout the thesis process. This approach has been described by Archer (1995) as subjective and situation-specific. This situation also states that research findings by research through design will be reliable and valid only in the place, time, and conditions where the action takes place (Archer, 1995). However, such concerns were not present during the research process because interviews and focus group studies were conducted with multiple experts in the field and people from all user types.

This thesis explores the product design process and conceptualizes proposals about 'physical' and 'digital' design elements for designers, considering user-product interaction in clinical practice training. The physiotherapists who participated in the research during the development process of the clinical practice product did not have enough experience collaborating with the designers. Therefore, it took much work to get feedback from the participants in the field studies and to have them contribute to the product development process.

To overcome this disadvantage, fully functional prototypes of the Physiocircle training product have been designed. The research-through-design process, which led to identifying Physiocircle designs, required significant time and effort. Releasing a prototype for each version, with all functions working and production realized, caused the preparation process for focus group studies to take a long time. In addition, expert support was received for coding the mobile applications and the electronic card development processes that the researcher did not have the competence. For all these reasons, the 3rd version of Physiocircle could not be included in the thesis process, and possible improvements were presented as suggestions.

In addition, the thesis's delivery time and the prototype production length did not allow field studies to be carried out with participants from different universities. Expanding research with institutions providing chest physiotherapy training could have provided more comprehensive and guiding outputs for designers, provided the researcher had more time to work on it.

## 6.4 Benefits of Physiocircle to Clinical Practice

To determine the contribution of the Physiocircle product to education, the research that should be carried out with physiotherapy instructors and students could not be done because sufficient time and conditions needed to be provided. However, the design details and technical details of the Physiocircle were determined using literature research and field studies. For this reason, it is expected to contribute to clinical practice training in the following subjects;

• Desired number of patient cases: Trainers can upload any number and variety of patient cases to the system using the desktop application. So students can practice physiotherapy using these cases.

• Universality in Education: The "Case Pool" system records all cases in the Physiocircle system in the cloud system. In this way, it is ensured that all students can benefit from the cases created by instructors around the world.

• Independent Physiotherapy Practice: Students can exercise whenever and wherever they want by using the physiotherapy vest, mannequin, and tablet application. In this way, each student can plan their time to practice physiotherapy by their available time.

• Digitalization in Education: Thanks to the wireless connection and sensor technology, all physiotherapy exercises completed by students are recorded in the cloud system. These data are shown to the students instantly, allowing them to correct their data, such as violence, speed, and location. In addition, it is shared with the instructors via the desktop application, ensuring that each student is followed and evaluated in the digital environment.

## 6.5 Recommendations for Further Study

The Physiocircle training system created as a result of this thesis is suitable for use as clinical practice equipment in manual chest physiotherapy courses. If requested in the future, the Physiocircle product can be provided to designers or physiotherapists who would like to do further research in this field. In this way, different perspectives can be explored, such as the effect of using the clinical practice product in physiotherapy education or the contribution to the development of students and the interaction of instructors with new technologies.

In addition, the product development process presented regarding manual chest physiotherapy and the outcomes of this process can also be used for different health disciplines that need clinical practice training. This way, product development processes can be carried out for different disciplines, such as medicine, dentistry, and nursing, and new ones can be added to the outputs.

Lastly, it will be beneficial for designers to reveal the design process in more detail and in a more diverse way, by participating in the research in different physical therapy and rehabilitation faculties and conducting a more comprehensive field study.

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# APPENDICES

## A. Expert Interview Guide (English Version)

**Session 1 - Understanding of Manual Chest Physiotherapy**

At the beginning of the interview, questions were asked to confirm the knowledge in the literature research about manual chest physiotherapy and to obtain more information. In this way, information was obtained about the points to be considered in the design of Physiocircle V1.

Q1 - Can you give information about the Manual Chest Physiotherapy method, how is it applied and in which conditions/diseases is it a needed treatment?
Q2 - Are there different application methods used in Manual Chest Physiotherapy? If there is; Can you give information about the application of these methods?
Q3 - What are the responsibilities of physiotherapists during Manual Chest Physiotherapy? In which subjects should they develop themselves and have experience?

**Session 2 - Understanding of Common Education at Chest Physiotherapy**

In this part of the interview, questions were asked to obtain information about the education system currently used. By obtaining detailed information about the current education system, needs and wishes were determined.

Q4 - Can you give information about chest physiotherapy training? Which courses are covered in the content? How long is the training period?
Q5 - Could you tell us about a lecture period in which chest physiotherapy training was given? What are students held responsible for this semester?
Q6 - What competencies are students expected to gain upon completion of these courses?
Q7 - Are there any methods you use to improve the training process? If there is; how do you use them?

**Session 3 - Suggestion and Ideas about Training Tool**

In the last part of the interview, questions were asked to understand the participant's suggestions and ideas about the educational product to be designed.

Q8 - What are the negative or missing points in the current chest physiotherapy training according to you? Why?
Q9 - What do you think can be done to eliminate these deficiencies or negative points?
Q10 - In your opinion, what should be the usage process of a product to be used in chest physiotherapy training? Should it be physical or digital? Or should it include both?

## B. Expert Interview Guide (Turkish)

**Session 1 - Understanding of Manual Chest Physiotherapy**

Görüşmenin başlangıcında manuel göğüs fizyoterapisi hakkında literatür araştırmasındaki bilgileri teyit etmek ve daha fazla bilgi edinebilmek için sorular sorulmuştur. Bu sayede Physiocircle V1 tasarımında dikkat edilmesi gereken noktalar hakkında bilgi edinilmiştir.

Q1 - Manuel Göğüs Fizypterapisi yöntemi hakkında bilgi verir misiniz? Nasıl uygulanır ve hangi durumlarda/hastalıklarda ihtyiaç duyulan bir tedavi yöntemidir?
Q2 - Manuel Göğüs Fizyoterapisi içerisinde kullanılan farklı uygulama yöntemleri var mı? Var ise; bu yöntemlerin uygulanma şekli ile ilgili bilgi verebilir misiniz?
Q3 - Manuel Göğüs Fizyoterapisi esnasında fizyoterapistlerin sorumlulukları nelerdir? Hangi konularda kendilerini geliştirmeleri ve tecrübe sahibi olmaları gerekir?

**Session 2 - Understanding of Common Education at Chest Physiotherapy**

Görüşmenin bu kısmında şu an kullanılan eğitim sistemi ile ilgili bilgi edinmek amaçlı sorular sorulmuştur. Mevcut eğitim sistemi hakkında detaylı bilgi edinilerek ihtiyaç ve istekler belirlenmiştir.

Q4 - Göğüs fizyoterapisi eğitimi hakkında bilgi verebilir misiniz? Hangi derslerin içeriğinde anlatılmaktadır? Eğitim süresi ne kadardır?
Q5 - Göğüs fizyoterapisi eğitimi verilen bir ders dönemini anlatır mısınız? Öğrenciler bu ders döneminde nelerden sorumlu tutuluyor?
Q6 - Bu dersler tamamlandığında öğrencilerin hangi yetkinlikleri kazanması bekleniyor?
Q7 - Eğitim sürecini iyileştirmek için sizin uyguladığınız yöntemler var mı? Var ise; bunları nasıl kullanıyorsunuz?

**Session 3 - Suggestion and Ideas about Training Tool**

Görüşmenin son kısmında katılımcının tasarlanacak eğitim ürünü ile ilgili öneri ve fikirlerini anlamak için sorular sorulmuştur.

Q8 - Mevcut göğüs fizyoterapisi eğitiminde size göre olumsuz ya da eksik olan noktalar nelerdir? Neden?
Q9 - Sizce bu eksiklikleri ya da olumsuz noktaları gidermek için neler yapılabilir?
Q10 - Sizce göğüs fizyoterapisi eğitiminde kullanılacak bir üründe kullanım süreci nasıl olmalı? Fiziksel mi, dijital mi olmalı? Ya da her ikisini de içermeli mi?

## C. Consent Form

Değerli Katılımcı,

Bu çalışma Orta Doğu Teknik Üniversitesi Endüstriyel Tasarım Bölümü yüksek lisans öğrencisi Selami Erdoğan tarafından yüksek lisans tezi için bir araştırma niteliğinde olup, fizyoterapi eğitiminde kullanılacak yardımcı eğitim ürün tasarımının ürün-kullanıcı etkileşimini gözlemlemek ve kullanıcıların yorumları hakkında bilgi edinmek amacıyla gerçekleştirilmektedir. Yapılacak olan görüşmenin tahmini 90 dakika sürmesi beklenmektedir. Kimliğiniz ve görüşme sırasında vereceğiniz kişisel bilgileriniz saklı tutularak, sizden ve katılımcılardan edineceğimiz konu ile ilgili görüşleriniz yalnızca tez kapsamında kullanılacaktır.

Çalışmanın sonucuna dair bilgi almak isterseniz, ilgili iletişim adresi üzerinden irtibata geçebilirsiniz. Çalışmaya verdiğiniz destek ve katkı için teşekkür ederim.

Katılımcı İmzası

Araştırmayı yürüten kişi,
Selami Erdoğan
selami.erdogan.94@gmail.com

Dear Participant,

This study is a research study conducted by Middle East Technical University Industrial Design Department graduate student Selami Erdoğan for his master's thesis, to observe the product-user interaction of the auxiliary training product design to be used in physiotherapy education and to obtain information about the comments of the users. The interview is expected to last approximately 90 minutes. Your identity and personal information you will provide during the interview will be kept confidential, and your views on the subject we will obtain from you and the participants will only be used within the scope of the thesis.

If you want to get information about the result of the study, you can contact via the relevant contact address.
Thank you for your support and contribution to the study.

Signature

The person conducting the research
Selami Erdogan
Selami.erdogan.94@gmail.com

## D. Finalized Code Structure

**Manual Chest Physiotherapy Education**

- **Contents of Manual Chest Physiotherapy**
  - Percussion
  - Vibration
  - Shaking
  - Positioning
  - Postural Drainage
  - Hands-on Experience
- **'Traditional' Chest Physiotherapy Education**
  - Syllabus
  - Course Material
  - Quiz & Exam
  - Evaluation Criterion
  - Responsibility of Students
  - Responsibility of Instructors
- **Barries & Limitations for Practice-Based Education**
  - Number of Students
  - Lack of Equipment
  - Limited number of Instructor
  - Financial Budget of Faculties
  - compliance to technology
- **Personal Solutions for Qualified Education**
  - Alternative Applications
  - Knowledge transfer
  - Gamification
  - 'Match-up' Approach
  - chance of use context